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ON THE VACANT REGIONS OF THE SKY*

E. E. BARNARD.

The vacant regions of the sky, as we are made more familiar with their peculiarities through photography, become of more interest and importance. I think some of them will before long excite as much study and attention as do the nebulæ. In the past they have been regarded rather more in the light of curiosities than of objects that must have an important bearing on the structure of the Universe.

They have always appealed to me with an interest scarcely less than that of any other natural feature of the sky, and of late years their remarkable appearances as shown on Milky Way photographs has become decidedly fascinating. The relationship that they so often bear to the nebulæ has only added to the puzzle as to what their existence really means. In most of these peculiar features the easiest and apparently the correct solution is that they are real vacancies among the stars. There are some parts of the sky, however, in which they do not so readily offer themselves to this explanation. But I believe these last are quite a different class of objects and should be studied differently. First of all, most of these blank regions, say anywhere north of 20° south declination, look like real openings or rifts among the masses of stars, and though they are sometimes suspiciously well defined at their edges, as in the case of the remarkable black hole 12′ in diameter, in the middle of the dense star cloud, in (1855.0) α 18^h 7^m, $\delta - 18° 20'$, they still impress one as being actual holes. In most cases I have had the impression that the Milky Way, where these occur, is a more or less thin sheet of stars with no great depth of thickness away from us. If such were the case there would be no difficulty in accepting these blank spaces as actual rifts or holes in this sheeting of stars—why they should be there is of course another matter altogether, with which I have nothing to do.

When we search more extensively into the subject we find that

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these vacant regions are not dependents of the Milky Way entirely, for we find them also in the nebulæ, and in or connected with the clusters. The rifts of Lord Rosse in Messier 13 (the great clusters of Hercules) are not such striking features with powerful telescopes as we have been led to believe, for they are filled with a luminosity which takes away their blackness when seen in a large telescope, and I do not believe that they penetrate very deeply into the cluster, while others—and perhaps more remarkable vacancies, rifts and lanes—are found in the less dense outlying regions of this cluster and indeed in many of the other clusters—notably in Messier 5 Libræ. These are not evident however in ordinary observations or photographs, because of their small scale.

But if we come back to the Milky Way where their size makes them apparent even to the naked eye, and where they make such surprising appearances on photographic plates with wide angle lenses, we shall find that they readily separate themselves into two classes quite distinct in physical appearance, and I believe quite different in their origin.

Those lying north of the southern part of Ophiuchus are purely black and give the appearance of empty space beyond, seen through rifts or holes in a dense sheeting of stars. I think this description will essentially cover these peculiar features elsewhere outside of Scorpio and Ophiuchus.

In Ophiuchus and Scorpio in the region bounded by α 16^h 0^m to 17^h 40^m δ $-20°$ to $-45°$ the appearance of these vacant regions is wholly different. Here occur vacancies within vacancies; that is there are vast regions almost entirely free from stars, in a surrounding region thick with small stars. These regions seem veiled over with some sort of material in which occur blacker spaces, as if all this part of the sky were involved in a thin faint nebulous sub-stratum which partly veils the blackness of space beyond. In this, apparently, occur rifts and openings giving a clearer view of space. A description of these peculiarities is difficult and is apt to be misleading. The pictures themselves should be carefully examined before a just conception can be had of these remarkable features. The most striking thing however, is their dissimilarity to the ordinary blank spaces elsewhere in the Milky Way. The region of Theta Ophiuchi, to a distance of 5° or 6° all around that star, is perhaps the most remarkable because of the minuteness and sharpness of some of these details and their peculiar forms. To the east of Theta, between it and 58 Ophiuchi, is a great chasm in which one or two considerable stars shine.

PLATE XIII.

NORTH

VACANCY IN THE MILKY WAY NEAR THE STAR THETA OPHIUCHI

R. A. $17^h\ 24^m$ Dec. South $25°.5$

1905 June 30

Scale 1 inch = $1°.1$ Exposure $3^h\ 45^m$

Theta Ophiuchi is near the right hand edge of plate.

PLATE XIV.

VACANCY IN THE MILKY WAY NEAR THE STAR THETA OPHIUCHI.

R. A. 17h 4m Dec. South 27°.3

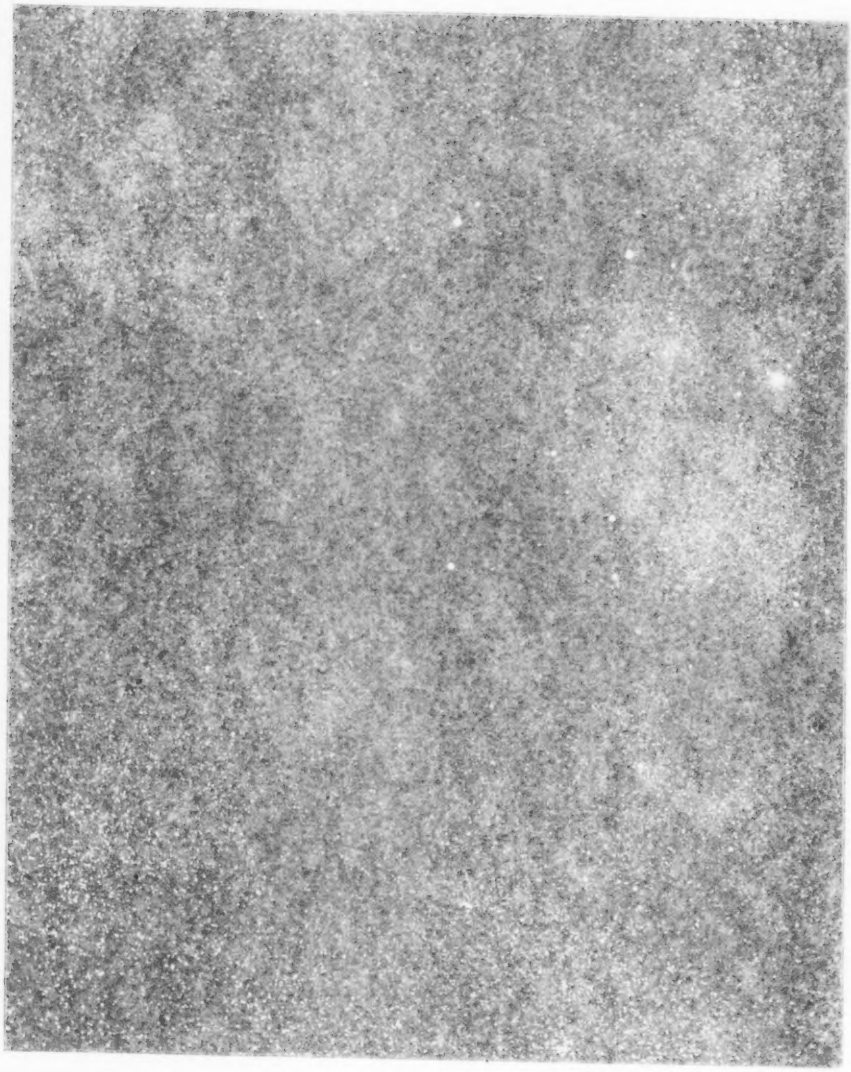
1905 June 28

Scale 1 inch = 1°.1 Exposure 4h 35m

Theta Ophiuchi is near the upper and lower corner of the plate.

PLATE XIII.

NORTH



VACANCY IN THE MILKY WAY NEAR THE STAR THETA OPHIUCHI

R. A. 17h 24m Dec. South 25° 5

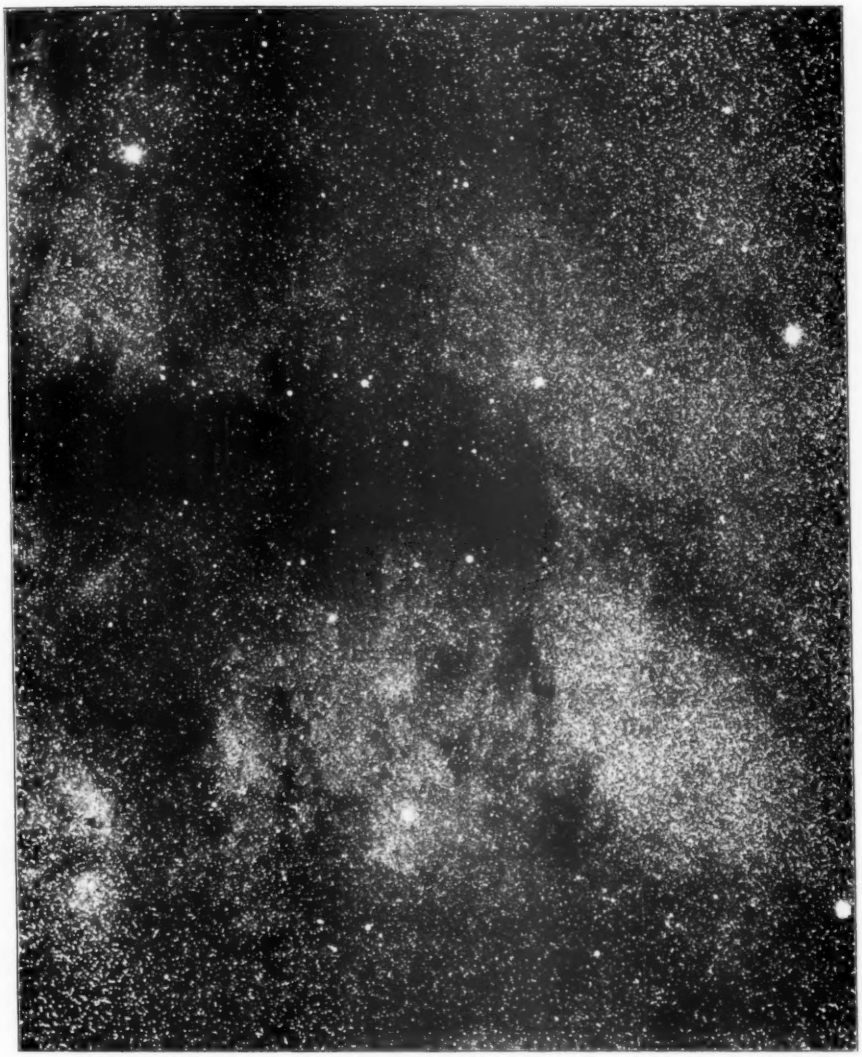
1905 June 30

Scale 1 inch = 1°.3 Exposure 3h 45m

Theta Ophiuchi is near the right hand edge of plate.

PLATE XIV.

NORTH



VACANCY IN THE MILKY WAY NEAR THE STAR THETA OPHIUCHI.

R. A. $17^h\ 4^m$ Dec. South $27°.3$

1905 June 28

Scale 1 inch = $1°.1$ Exposure $4^h\ 33^m$

Theta Ophiuchi is near the upper left hand corner of the plate.

This vacancy swings westerly under (south of) Theta for some 5 degrees where it comes to an abrupt stop at a smaller hole with a most peculiar ragged formation around its edges. This dark rift where it passes under Theta is noticeable to the naked eye. If we follow out the original chasm we shall find that it goes northward and then turns west in a shattered form which strengthens out into a definite lane, which after running some 15° westward finally connects with a remarkable vacancy in the dense sheeting of small stars near Rho Ophiuchi. This is a vacancy only in the sense of scarcity of stars, for it is filled with one of the most remarkable nebulæ in the heavens—that about Rho Ophiuchi. This is the most puzzling region that I know of in the sky. The lane running from it to the east is narrow and sharply terminated at its edges. The nebula itself with its extensions, covers some 5° of the sky. The principal condensations are at or near Rho Ophiuchi, but it extends southward and has at least three other condensations at the stars cord, S. D. 24°.12683—4, 22 Scorpii and Sigma Scorpii. It is specially strong about Sigma Scorpii. It apparently also strongly involves Antares, but whether this is accident of projection or not does not seem apparent. There is no question however as to the condensation being actually at Sigma Scorpii. It is symmetrical with respect to that star, and has considerable detail in it. This would make Sigma Scorpii the brightest nebulous star outside the Pleiades. In widely diffused waves this nebulosity extends as far as Tau Scorpii.

The blending of this great nebula into the surrounding region, where it seems to mingle with the material of the vacancies, makes it hard to tell where the nebula leaves off. This peculiarity is extraordinary and I know of no similar case. There is a slight suspicion that certain outlying whirls of the nebulosity have become dark and that they are the cause of the obliteration of the small stars near. I think this is fanciful however, for the irregular vacancy in which it lies connects readily with the vacant lane running east to the region of Theta Ophiuchi. No one would suspect for a moment that this lane is anything but an actual vacancy among the stars. There is a strong suggestion here that all this region for many degrees, including the nebula of Nu Scorpii is involved in diffused nebulosity, and that the various condensations are simply the brighter parts of this matter.

I would say that the nebulosities of this region were first found by me at Nashville, Tenn., while comet seeking as early as 1883, and later at the Lick Observatory with the comet seeker, and 12-

inch; but their remarkable appearance was not fully known nntil they were shown by my photographs of that region in 1893.

In Popular Astronomy, Vol. 5., p. 229 for September 1897 where a photograph of the Great Nebula is given I have called attention to the apparent connection of the great nebula with the brighter and fainter stars of this region, and the probability that the apparent smallness of the stars of theMilky Way is due to actual smallness as compared for instance with Antares, Sigma Scorpii, etc. I think the present photographs, which were made by me at the Solar Observatory, Mt. Wilson, California, during the past summer of 1905, make this more evident today than it was from the information had some ten years ago.

The region of Theta Ophiuchi is so closely related in many of its phenomena with that of Rho Ophiuchi that they really go to make up one most extraordinary picture which, unfortunately, is too large to be covered by any one plate. The two regions are connected by straggling vacancies, and the structural details, though different, are of the same order of vacancies. This region does not even stop at Theta Ophiuchi, but extends to, and beyond, 58 Ophiuchi, where a new order of peculiarities appears. Yet taken in connection with those just mentioned, the small clouded masses of what apparently is nebulous matter (of which 58 Ophiuchi is the center) is in reality but a part of the great scheme of nebulous substratum that forms the wonderful region from five degrees northwest of Antares to three or four degrees beyond 58 Ophiuchi, and which may be ten or fifteen degrees wide north and south. A description of the region immediately connected with Theta Ophiuchi is not an easy one. It is so complicated with unusually small definite details that one hardly knows what to liken it to. It looks almost like the work of a decorative artist so singular are some of the designs that appear upon it.

About 1° north of Theta Ophiuchi is a small S-shaped dark marking, and near it are several small black holes, while in the upper part of the picture the structural details seem to show that certain portions are pushed out towards us. To the east of Theta Ophiuchi is the broken region of 58 Ophiuchi. The most remarkable part of this region, however, is the extraordinary chasm to the south east of Theta Ophiuchi and which extends southwest under that star. Theta Ophiuchi itself is in the midst of a bright region which brushes out to form the rather abrupt edges of this great chasm.

In Sagittarius is a small star cloud which is conspicuously

noticeable to the naked eye. The photographs show this cloud to be specially remarkable for two black holes in its upper part. I have already referred to the larger of these holes (whose position for 1855.0 is α 18^h 7^m δ $-18°$ 20′). The east side of this hole is very sharply defined; the cutting off of the stars and the apparently feeble nebulous light is remarkably abrupt, as if some one had drawn its outline with a brush and black paint. The west side of the hole shoals slowly and is not abrupt. So definite is this black spot that several astronomers have thought that it may really not be a hole, and that it is perhaps an opaque mass of some sort that cuts off the light from this part of the Milky Way, against which it is seen in black relief. My own opinion is that it is a true hole through which we look out into space beyond where there are no more stars. In the hole is a conspicuous star which has a small attendant preceding. There are one or two other minute stars in the hole.

Below the middle of the picture is a group of nebulous stars, while running at an angle of 45° to the right of this group is what appears to be a bed of faint nebulosity remarkably definitely defined at its easterly edge.

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THE AIMS OF AN ASTRONOMER.*

EDWARD C. PICKERING.

Two titles have suggested themselves for my address of this morning, "The Aims of a Man of Science," and "The Aims of an Astronomer." The objections to the more restricted title are, that those of you who do not know me might think that I was about to discourse upon the inhabitants of Mars, or give you a technical paper interspersed with mathematical formulae of appalling length. From both of these courses I solemnly promise to abstain. The broader title might lead me into domains outside of my own studies, which are always particularly tempting to a specialist. The early aims of an astronomer must be passed over briefly to reach the more alluring field when they become, or should become, the aims of astronomy.

The first aim of a boy when he reaches manhood, and becomes

* Oration delivered in Sanders Theatre, June 28, 1906, before the Harvard Chapter of Phi Beta Kappa, Boston.

an independent unit in the community, is generally to acquire money or its equivalent. This aim for a time is perfectly legitimate. He is entitled to support, food, lodging, and clothing. Unfortunately, the savage has here a great advantage over civilized man. As soon as he attains his full strength and physical development, he becomes an important member of his tribe. He can hunt and fish, and can live in even greater comfort than his elders. The complex wants of civilization have changed all this. With us, a boy must get his education, and for years must be dependent on others when he should be self-supporting. Many of the evils of socialism, hatred of the rich, and fear of powerful organizations, are due to this cause.

If a man never gets beyond the money-making stage, he can hardly be called a student of science. Let us assume that he is intellectually a success and attains a college position. He will never be rich, but since he is as well off as his associates he is not poor. His next aim is likely to be personal fame—a better object than wealth, but still a purely selfish one. In this stage of his development, he tries to obtain honorary membership in societies, degrees or other honors, instead of waiting for them to come to him unsolicited. He makes reclamations of priority, and deposits sealed packages in the safe of the French Academy, so that if any one else should make the same discovery he can call for his package and prove that he is entitled to the entire credit, since he was first. If he is young, he attacks the work of some older man, and thus gains notoriety, even if his charges are disproved or ignored. The specious plea, "I feel obliged, in the interest of science, to point out that my friend, Mr. A, is entirely wrong," seldom conceals the true motive.

The next aim is higher and is for fame, not for himself but for his college, his city, or his country. Enthusiasm for his state is dampened when the latter attempts to tax scientific institutions, instead of aiding them, as is done in all other civilized countries. For years, nearly all English mathematicians, following Newton, dealt with fluents and fluxions, while the Continental mathematicians, following Leibnitz, used differential coefficients. The astronomers who gave the principal credit to Adams for the discovery of Neptune were nearly all Englishmen, while few Frenchmen admitted the claims of any one but LeVerrier.

This brings us to what should be the true aim of the student of science, the advancement of human knowledge and the determination of the laws regulating the physical universe. His sole object should be to secure the best possible results, and he must

be ready to make any sacrifice of his personal wishes for this end. Astronomy thus becomes international, and wholly impersonal. To how many of us is this the one and only aim, regardless of all selfish considerations? We must not expect too much of poor human nature, and yet it can do no harm to make our ideal a high one. No man is likely to surpass his ideal, and even if it is so high that he cannot hope to reach it, he may go further than if he only tries to attain money or fame. The aims of the astronomer thus become the aims of astronomy, and there is no subject to which he can better give careful attention.

No man can hope to advance science now, as has been done in the past. Think of writing a book which not only would survive and be useful for two thousand years, but which for fourteen centuries should be the great work, and practically the only authority, of its kind. Yet this is the position held by the *Amalgest* of Ptolemy. During the greater portion of this time it was reproduced again and again by laborious hand-made copies into which errors crept, were repeated and multiplied. By far the best copy bridges more than half the interval, since it was clearly written in the uncial characters of the ninth century. It is deposited in the Bibliothèque Nationale in Paris, and in 1883 was kept in one of the show-cases of that institution. It contains a catalogue of more than a thousand stars, which is perhaps that prepared by Hipparchus, nearly two centuries earlier. It not only gives the positions, but the brightness, of all of these stars, and shows that at the beginning of the Christian era the appearance of the heavens was nearly the same as at present. Even a careful observer, without instruments, would have difficulty in detecting any differences during these two thousand years. But for the errors in copying mentioned above, the *Amalgest* would still give us valuable information regarding the secular changes in the stars. No worker in science knows whether his results will have any value a century hence. The work of the older astrologers was supposed, at that time, to be as valuable as that of the astronomers. No one could tell that the work of the early chemists was of more importance than that of the alchemists. Until within a century, the estimates of the light of the stars as given in the *Amalgest* were considered as of little scientific value. One man of genius, Sir William Herschel, recognized the value of accurate determinations of stellar brightness, and in 1796 to 1799 he published four catalogues of 1905 stars, covering two thirds of the northern sky. It was my great good fortune, when visiting his grandson in 1883, to discover the manuscript of two other

catalogues, which when published rendered the work complete for the entire portion of the sky visible in England. For eighty years they had lain on the shelf, unknown to astronomers, and their existence was not even suspected. Although the observations had been made with the greatest care, the six catalogues were not in a form that could be used. The necessary reductions and publications of the results were made at the Harvard Observatory, and thus we were enabled to present to astronomers a catalogue of nearly three thousand stars, showing their brightness a century ago and determined with an accuracy which has only been equalled within the last few years.

These are examples of great successes by clear-sighted men of genius who little suspected how highly their work would be appreciated after they were dead. To offset this, there are whole generations of astronomers whose lifework is now of little or no value. Let each man ask himself to which class his own work belongs. Only the future can decide with certainty, but we can at least improve methods which will certainly do good, and can do no harm.

Unfortunately, astronomical research has now become so expensive that large sums are required to carry it a step beyond what has already been accomplished. A word must therefore be said to men and women of wealth who desire to aid this science by gift. Many persons have learned how to accumulate great fortunes, but few have succeeded in giving away wisely large sums of money for scientific work of the highest grade. It is strange that a shrewd business man, who by lifelong labor has accumulated a fortune, if he wishes to give it away, should not use the same skill that he did in acquiring it. When buying a mine he sends experts to examine it, and assures himself that he will obtain an adequate return. When converting his money into scientific results, he should similarly satisfy himself that his plan is a good one, and that it will fill a real want. Let us, therefore, hereafter have no needless duplication of observatories, no great telescopes that are idle, no costly expeditions which, owing to insufficient preparation and lack of proper organization, will surely bring no adquate return. Money placed in the hands of a suitable committee would doubtless be spent to great advantage. The Rumford Fund of the American Academy and the Elizabeth Thompson Fund are thus well and wisely administered. But it is pitiful to hear from men of the greatest ability their needs for apparatus, assistance, or means for publication, which cannot be supplied by the few hundred dollars thus available. One of

the greatest needs of the physical sciences at the present time is a liberal fund for research, administered solely in the interest of science, and by scientific men. Some of the members of such a committee should be active workers in science, some of them older investigators still able to advise and judge, but lacking the energy of youth required to undertake research themselves. We have striking examples around us, even in this gathering, of suitable men who have passed the usual age of retirement. Some of them are still so active that they appear to accomplish even more than when they were younger. A fixed age of compulsory retirement sometimes leads to curious results. A Washington astronomer, when retired ten years ago, had all his work taken away from him and was not allowed to complete it even at his own expense. His life is still full of work and original suggestions. An army engineer from Cambridge, too old to serve the government, has been for years, since his retirement, engaged in the greatest problems of his profession, including the Panama Canal. The thanks of Congress lengthens a man's professional career by ten years. An admiral came near having his usefulness prolonged for four years, since he was so fortunate as to be born on the twenty-ninth of February. One of the greatest and most active of living astronomers will soon be retired just as he has completed and has ready for his use the most perfect apparatus yet contrived for measuring the places of the stars. When the plan for compulsory retirement was introduced at Harvard, I hoped that the Observatory might profit by it. Any man can complete his own work much more economically than another. I pointed out that at the Observatory we had much unfinished work, the time for my retirement was approaching, and I suggested that an appropriation should be made at once to complete it. The time is now much shorter, the work is still unfinished, and the appropriation has not yet been made.

A committee constituted as described above, and having liberal funds at their command, could advance astronomy in several different ways. My sympathy goes out to the young man who has taken a post-graduate course in astronomy, has studied abroad at a great and active observatory, and comes home to teach in a little country college. He wishes to continue his work in astronomical research with the new instruments and by the same methods he has just learned. His college has no money for such purposes, his associates do not sympathize with his wishes, and his time and strength are fully occupied with instruction. He writes a pathetic letter stating that if he had only a few

hundred dollars for a certain instrument he would gladly give his own time to the proposed work. Last month I received a letter from a Jesuit priest in Buluwayo, a thousand miles from the civillzation of Cape Town, giving me certain definite meteorological facts resulting from a year's careful observation in that wonderful climate. He described some important observations he wished to make if he only had five hundred dollars to purchase a mounting for his telescope. The committee would not only give such a man the required aid, but also the encouragement, which is often still more highly prized. The man of genius is, in many cases, sensitive, retiring, unable to promise results, or to make known his needs. He must be sought, treated with tact, and encouraged. If transplanted to other surroundings, or even if supplied with better appliances, his usefulness may cease. No amount of organization would help him; in fact any interference with his plans is likely to spoil them.

On the other hand, a great observatory should be as carefully organized and administered as a great railroad. Every expenditure should be watched, every real improvement introduced, advice from experts welcomed, and, if good, followed, and every care taken to secure the greatest possible output for every dollar expended. A large part of the income is used for salaries, heating, lighting and repairs. Accordingly, a small increase in the resources will produce a disproportionate increase in the scientific results obtained. Much of the work of a large observatory is routine, studying thousands of stars in the same way, the work extending, in some cases, over many years. A great saving may be effected by employing unskilled and therefore inexpensive labor, of course under careful supervision. In this way, a great increase in the results can be obtained from a moderate expenditure, and the amount can be closely estimated in advance. The clerical work is largely copying numbers on prearranged forms, and computed, in which only a knowledge of the four rules of arithmetic is needed. Such work must always be checked by an experienced assistant, and all errors detected by duplicate or triplicate computations. For such routine work we pay from twenty-five to thirty cents an hour, which is much above commercial rates for similar work. Prices are much lower in Europe, and supervision would also be cheaper there. An exhibition of wood-carving and embroidery has recently been held in Berlin. Some beautiful specimens were shown which had been paid for at the rate of half a cent to three cents an hour. Less skill would be required for much of the routine work needed in an observatory. If Asiatic

labor could be employed, the prices would be still less, although the cost of supervision would be greater. In India, when tiger-hunting, the beaters go into the jungle armed only with a tin pan, which they beat violently with a stick. They thus frighten the tiger and chase him towards the tree in the top of which the bold hunter is safely seated, armed with a rifle. The beaters are paid the liberal sum of three to four cents a day, which is increased to six cents if the work is done properly and the tiger is killed. The family of the beater would probably prefer that he should engage in almost any department of astronomical research. The most savage despotism of modern times was overthrown, and peace and comfort brought for the first time to the millions of inhabitants of Central Africa, by soldiers the greater portion of whom were paid at the rate of five cents a day.

It is not unusual for the successful to criticize those who are richer and more powerful than themselves. In some countries this is done with the aid of dynamite bombs. In others (I mention no names), it takes the form of newspaper attacks on wealthy men, corporations, trusts, insurance companies, and railroads. When we begrudge the hundreds of millions acquired by Standard Oil, should we not remember how much of it was earned by the genius of the men who evolved the most perfect business organization the world has ever known? If we say that Mr. Carnegie ought to distribute his millions among his workmen, let us recall the fact that he was able to sell three pounds of steel for two cents, by giving to the Bethlehem Steel Works an administration and management of every detail, superior to that of any similar corporation in existence. A great railway system may misuse a large sum of money, and yet this is a trifle compared with the thousands of millions of dollars it brings to the country by supporting a vast community of farmers who are enabled by its aid to send the products of their farms to the markets of the world. If we apply these principles to astronomy we may expect the same advance that has been accomplished in commerce, agriculture, and manufactures. Who would object to a trust, whose sole objects would be increased production, reduced cost to the public, and no profit to those forming it? The advantages of careful administration in scientific work are illustrated in a plan I detailed at the Franklin Bi-Centenary, a few weeks ago. A telescope of the largest size entails great expense, but might produce a collection of photographs which would furnish useful material for study to half the astronomers of the world. My plan proposed that a reflecting telescope of

seven feet aperture should be mounted in the best possible location, probably in South Africa, and kept at work photographing the sky throughout every clear night. An international committee of astronomers would decide to what special work the instrument should be devoted, and the photographs, or copies of them, would be distributed throughout the world to any astronomers who would make proper use of them. Copies of any or all of the photographs would be sold at cost to whoever wished for them. An astronomer of any country, prepared to undertake a particular research, would be furnished with the best photographic material that could be obtained in the present condition of science. Means would also be provided him for making suitable measurements, for reduction of the results, and finally for publication. Any competent astronomer, however isolated, would thus be enabled to carry on his researches amid his own surroundings, as well as if he were at the greatest observatory in the world. The man best qualified to discuss the results often has very little skill, even if he has the time, to take the photographs. Conditions would thus be provided which would give the best results for each portion of the work, as in any well-organized industrial enterprise. The donor would be assured that he had supplied material for study for the most expert astronomers of all countries, instead of for those at a single institution. A careful estimate of the cost of carrying out this plan showed that it would be less than half a million dollars, or about one third of that of establishing an observatory of the first class, like those now existing.

The greatest problem of all for the committee to consider, and that which would really include all the others, would be to determine which departments of astronomy were being neglected, and which were receiving attention that could better be applied to other subjects. A committee without money could accomplish little, but if a moderate sum were placed at their disposal, with the promise of more if it were well expended, astronomical science might be lifted to a new and higher plane. Suppose the subject selected was double stars. Many men of genius have done excellent work with small telescopes and poor micrometers. Such men would be supplied with the best instruments they could use to advantage, and money for recorders, computers, and publication, if they desired it. Various systematic examinations of all stars in certain regions, and brighter than a given magnitude, have been made for the discovery of new doubles. This work should be completed for the entire sky, both north and south, according

to the same system, and with similar instruments and conditions.

A certain minimum number of accurate measures should be obtained of all double stars. Computers of orbits complain that many important objects are neglected, while numerous superfluous observations are made of other interesting pairs. The committee would communicate with observers, offering aid if they would supply this want. If not, owners of large telescopes would be asked to allow them to be used for this work, the committee furnishing the necessary micrometers and employing young astronomers as observers who would get their training, if possible, from experienced specialists in this class of work. Computers of orbits would be aided in the same way, and their work might thus be greatly improved in quality, and increased in quantity. Directors of observatories could get most valuable advice and help from the committee, and when a new observatory was established, its plan of work could thus be greatly improved. The Harvard Observatory would gladly welcome and profit by such advice.

The committee should not stop with existing problems. When a new line of research, like measuring the heat of the stars, is proposed, they should at once investigate it and, if the results are promising, test it. If it proved successful, they should carry it as far as present means permit. In this, as in securing the coöperation of existing observatories for any of the great problems now before us, there seems to be no limit to the results obtainable by a wise administration.

The donor, as well as the astronomer, must be asked to consider first the interests of science. His name would necessarily always be associated with his gift, and would he not prefer a world-wide to a local immortality? There must be now many wealthy men trying to find some good use for the money they cannot take with them out of this life. The hardest problem will be to find an active committee with no taint of selfish dross. This taint exists even among astronomers. There is no more permanent, economical, and efficient trustee than a great university with long-continued and honorable traditions. As with any other wish of the donor, it could secure and enforce unselfish management, as well as efficiency.

Industrial enterprises, half a century ago, were in nearly the same condition that science is in today. May we not expect in astronomy the same advance by coöperation and organization? If donors, trustees, and astronomers can thus be led to work for

scientific results alone, regardless of country or personal considerations, it will be the best return I can make for the great privilege of addressing the Harvard Chapter of Phi Beta Kappa.

RICHARD HINCKLEY ALLEN.

AUTHOR OF "STAR NAMES AND THEIR MEANINGS."

LUCY NOBLE MORRIS.

FOR POPULAR ASTRONOMY.

Richard Hinckley Allen, author of "*Star Names and Their Meanings*" was born in 1838, in Buffalo, N.Y., the son of Richard L. Allen and Sally Outram *née* Lyman of Northampton, Mass.

While the subject of this sketch was still at an early age, the family removed from Buffalo, N. Y. to Northampton, Mass; thence to New York City, and subsequently to Staten Island. Here the lad was under the tutorship of General Kargé, who was afterwards a professor at Princeton University. Later, Mr. Allen was graduated from the Columbia Grammar School under Dr. Charles Anthon, and then entered the class of 1860 at Yale, under the tutorship of Professor Dwight. Trouble with his eyes prevented graduation, and at the advice of his physicians the next two or three years were spent in travel.

From 1860 until 1885, Mr. Allen was actively engaged in the export business in New York City. His marriage to Miss Mary Collins Wallace, daughter of William C. Wallace of Newark and Chatham, N. J., occurred in 1873. Since that time he has resided in Newark, N. J., or at his country place on the Passaic River, near Chatham, New Jersey.

Farming, stock raising, amateur ornithology and astronomy were his pastimes, until one day, coming across the name "Hamal" for Alpha Arietis,—a name hitherto unknown to him,—he was led to follow up the matter with increasing interest as

the breadth of that somewhat unstudied subject unfolded itself.

Whatever Mr. Allen undertakes becomes, for the time, of first importance. To do anything in a half-hearted, slip-shod or inaccurate way is absolutely foreign to his nature. Rare old books on astronomy were collected from abroad, and from libraries in this country, notably that of Professor C. H. F. Peters.

The consulting of many books in his own library and in the Astor Library and the Lenox Library of New York and the Newberry Library of Chicago afforded him mental activity and a keen enjoyment, but apparently all this gathering together of a vast amount of material was for his own entertainment alone, until the solicitation of friends led to its further elaboration and use in "*Star Names and Their Meanings.*" Chief among those friends whose inspiration may be mentioned are Professors Hubert A. Newton and William D. Whitney, of Yale University. Professor Charles A. Young of Princeton University also lent valuable assistance and encouragement to the compilation of the book. It was printed in 1899, and at once met with favorable recognition from astronomers and others who take an interest in stellar nomenclature.

Morristown, N. J.
Oct. 19th, 1906.

The following letter to the Editor also contains important matter pertaining to "*Star Names and Their Meanings.*"

You are no doubt well acquainted with Mr. Allen's monumental work on "Star Names and their Meanings" which appeared some years ago, from the press of DeVinne in New York, and which was reviewed in *Popular Astronomy*, the *Observatory*, and many other periodicals at that time. I have always regarded it as an extremely interesting and useful addition to astronomical literature, and one that well deserved to be called a classic. As a reference book it is more likely to increase, rather than diminish, in value with time.

As pointed out, in an article in *The Observatory* (March 1902), Mr. Allen is not an astronomer in a professional sense,—this is the only writing from his pen on astronomical subjects,—and as in the case of other writers who have contributed monographs of worth the story of their own lives has been too often left unrecorded.

It was with great pleasure, therefore, that I received a few days ago the enclosed photograph and biographical sketch of Mr. Allen from Miss Morris, with a request for an opinion as to the desirability of its publication in *Popular Astronomy*, and that I should forward it to you. This I do, in the hope that your judgment should confirm mine. It seems not only fitting but highly desirable that your readers should be made acquainted with the man who could write a book of which the following comments have been made by Professor Holden; "a most useful and scholarly reference book, representing an immense amount of research:"—by Mr. Serviss, "It is both poetic and scientific; it shows

an immense amount of research and I cannot see how any one interested in astronomy could fail to be delighted with it; a unique work, a handbook of great value; a work that needed to be done, and that is done extremely well":—by Professor William Beebe of Yale: "a remarkable piece of erudition and research and very useful for reference:"—by Director R. T. A. Innes of South Africa, "the erudition and learning displayed overcome me entirely":—by Professor C. A Young, "I am delighted with the beautiful volume, I need not say how warmly I appreciate the indexes: they make the work complete in the free access they give to the immense mass of material otherwise hard to utilize. Every astronomical library would find it indispensable":—and by Professor Lewis Boss of the Dudley Observatory, "The author has approached the subject in the spirit of a scholar. It strikes me as admirable in every respect. We have too few instances of such rare, painstaking, thorough, and intelligent scholarship on this side of the water." I might add to Professor Boss's comments, that we also give too little encouragement to the few men who do endeavor by patient toil in this country to emulate the erudite scholars on the other side of the water. The cases cannot be counted on the fingers of one's hand, when, in this country good scholarship, patient endeavor, and earnest zeal have been thwarted and sometimes blighted by the indifference and the jealousies or the prejudices of fellow workers or of the public. It is surely highly gratifying to Mr. Allen, therefore, I should think, that his book has met with such a cordial and generous reception from both the professional astronomer and the general public. It is equally fitting that his biographer should be the young lady who assisted in preparation of his book.

HERMAN S. DAVIS.
American Editor of the
Astronomischer Jahresbericht.

Dover, Delaware, Oct. 31st 1906.

THE NUMBER OF THE STARS.

WINIFRED GIBSON.

An intensely interesting article appears in the *Monthly Notices* Vol. LXVI, No. 7 in regard to the number of the stars, written by Miss Winifred Gibson B. Sc., Jessel Student, University College, London. The mathematical discussion is in some respects new and it is carried forward into details that will certainly claim the attention of mathematicians and astronomers very generally. We give below the summary of the paper as written by the author. [ED.]

(*a*) Any character of a star which may be supposed to follow a chance distribution of frequency would enable us, if the "tail" of the distribution were known, to form some estimate of the total number of stars.

(*b*) The only character which appears to be at present available is magnitude; but magnitude is a physiological rather than

a physical character, and the chance distribution must only be applied to quantities of the latter kind.

(c) An investigation was first made of the relation between magnitude and distance. So far as the lucid stars are concerned there appears, on the basis of parallaxes at present determined, to be no decrease of parallax with increase of magnitude. There is no sensible correlation between the two. A sensible relation was found between parallax and proper motion sufficient to indicate that parallax is really a measure of relative distance, but the relation was not intense enough to enable any useful prediction of parallax to be made from a knowledge of proper motion. On the other hand, both visual and photographic magnitudes were found to be sensibly associated with color. Investigating further the relation between parallax and magnitude, it seems probable that definite variations of parallax are associated with magnitude, and are possibly of a periodic character; but a continuous change of one character with the other is not appreciable—at any rate on the present data—so far as the lucid stars are concerned.

(*d*) Taking light as the variable, it was found that no curve approaching the Gaussian type could possibly give the frequency of stars for various quantities of light. The general type of the distribution was seen to be of the form

$$y = \frac{C}{(x+b)^n}$$

If we put $b = 0$, this gives us, when we replace light by magnitude and y by $N_x = \int_x^\infty y dx$, the form

$$\log N_x = C' + n'm$$

where m is the magnitude and C' and n' are constants. This form may be directly deduced by the assumptions—

(1) That Fechner's law in *its simplest form* holds;

(2) That magnitude varies inversely as the square of the distance;

(3) That the stars are scattered uniformly through space.

All these hypotheses are almost certainly erroneous, yet it is remarkable how closely their combined errors give the true result. Pickering has already considered the application of a formula of the above kind, and shown that it still approximates to the observed frequencies.

Pickering's formula can be made to give better results, in the ratio of 135 to 103 (testing by the residuals), by choosing some-

what different constants. It can be improved in the ratio of 135 to 40 by supposing b is not zero, or that the number of stars of the system to which the lucid stars in the main belong is not infinite. It is then seen that the deviations in the frequency from the proposed formula are fairly closely periodic, the period being 2.5 magnitudes. In this manner the calculated frequencies up to magnitude 6.75 can be obtained with a mean square-root residual of less than four stars. Greater exactitude can hardly be hoped for until the probable error of the counts is far less than at present.

(*e*) The general conclusion is reached that magnitude is not, so far as the lucid stars are concerned, mainly, if at all, a question of distance. The arrangement of these stars differs from a pure random distribution throughout space, based upon magnitude as a function of distance, by a periodic variation in frequency which appears somewhat similar, although of only half the period, to that which occurs in the relation of parallax to magnitude. Further, a better fit is obtained for the frequencies of the lucid stars if we assume the asymptote to the frequency curve not to be at zero light. This suggests that the system to which the lucid stars belong may possibly be a limited system of a definite and not random structure.

This work was undertaken in the Drapers' Company Statistical Laboratory at University College, London, and I have to thank the staff there for suggestions and assistance during the progress of the work, in particular Mr. J. Blakeman, M. Sc., for aid in the very laborious calculations of which only the results appear in this paper.

ON THE OBSERVATION OF VARIABLE STARS.

III. Mean Light-Curves.

P. S. YENDELL.

For Popular Astronomy.

In the cases of stars of short period and of the Algol type, where the light-changes are regular in their course, and the period either regular or subject to variations whose law is known, these light-changes may be shown with a very close approach, probably, to their actual course, by the formation of what is called a mean light-curve. This curve is made for the purpose of showing the nature of the star's variations through its whole period, to determine the relative position, in this period, of its maxima and

minima, and especially to utilize observations from which, on account of their isolated or scattered dates, it is impossible to deduce phases by means of the graphic method detailed in the last paper.

The first step toward forming such a curve is to compute an accurate ephemeris of the star's maxima or minima, from the best elements to be had. In forming such an ephemeris, a table of multiples of the star's period, from one to ten, then by tens to a hundred, by hundreds to a thousand, and so on; and a table of Julian dates, are of very great use, saving not only much time but many figures, of which each figure affords an opportunity for an error. With the help of these, the ephemeris can readily be made for the dates alone which are needed, which is in itself a very respectable economy of labor.

As an example of the process we will use the mean light-curve the star U Cephei, *Autumn*, for the years 1899 to 1902, published in *The Astronomical Journal*, No. 551, p. 218. The preliminary steps, giving the processes for finding the light-values for the single observations, were detailed in the preceding paper.

It is advisable to form the light-scale from the whole body of observations of which it is intended to make use for the proposed curve, on the general principle that the greater the number of observations used, the more even and accurate will be the scale. In the present instance, the observations from which the scale was formed numbered nearly twelve hundred, and extended over fifteen years, from 1888 to 1902, inclusive. The step-intervals in the light-scale correspond closely with the photometric magnitude-intervals of the comparison-stars.

Having formed the ephemeris and reduced the observations, the next step is to arrange the light-values obtained according to their time-relation to the nearest computed maximum or minimum, whichever is taken as the datum-point; in the present case, the minimum. This relation is of course expressed by the interval of time between the recorded time of the observation and the computed time of the datum-phase, and is commonly designated the T—t; T standing for the computed time of the datum-phase, and t for the recorded time of observation. In the stars of the Algol-type, and those stars whose period is so short and the changes so rapid as to render the possible accuracy of determining their phases similar to that which is possible with the Algol-type stars, a correction to the observed time is applied, whose value depends upon the season of the year when the observations are made, and which is called the "light-equation."

It represents the apparent acceleration or retardation of the phase due to the progressive motion of the star's light, combined with the Earth's orbital motion, and its limit varies according to the star's distance from the ecliptic, from about eight minutes to nothing. (It should be understood that all dates in the ephemeris are in heliocentric mean time.) The formula and method of computing this correction lie beyond the province of this paper, and for the most of the beginner's occasions it would be a superfluous refinement.

It is convenient to assemble the observations in the order of their T—t, at first roughly as they are reached, in columns for their day or hour before or after the T; after all are arranged in this manner, they are then to be rearranged so as to fall in orderly succession of their T—t, from the earliest before T to the latest after it. In the case of the stars of the ordinary short-period type, it is convenient to have the T—t all positive, from minimum to minimum, showing the maximum in their course.

They should then be divided in the order in which they occur into groups of equal and convenient numbers, large enough to form fairly respectable means, and small enough to afford a sufficient number of these to indicate the course of the curve in as much detail as the quantity of material available will allow, especially near the maximum and minimum phases. In the example given, they are grouped in tens for the most fully observed portion of the curve, and for the beginning and end of the light-changes in fives, there being a considerable mass of material available. For a smaller accumulation of observations, groups of five are generally very convenient.

The means of the T—t's and of the light-values of these groups are then taken (preferably the weighted means are used for the light values, but not for the T—t's.).

In the example, the magnitude values alone were employed from the beginning of the process; this, however, is entirely a matter of detail, and does not in any way affect the rationale of the operation; but the general student will find it more convenient to use the step-values. In the present case, magnitudes of a definitive character were available, which is seldom the case in the present state of our knowledge of the subject.

We will now give three examples of the manner in which the normals (as the means are called) are formed; the groups are taken; the first from the beginning of the period of change, where, as toward its end, in the case of the Algol-type stars, observations are generally less frequent; the second from about the

middle of the decrease, where the change is most rapid; and the third from the interval of nearly stationary brightness at the minimum.

T−t h	T−t m	M	w		
−4	55	7.20	6	43.20	$T-t\ \frac{202}{5} = 40.4^m$
4	48	7.32	7	51.24	
4	41	7.20	6	43.20	
4	34	7.56	12	90.72	$\frac{271.56}{37} = 7.34^M$
−4	24	7.20	6	43.20	
	202		37	271.56	
−2	15	7.92	11	87.12	$T-t\ \frac{96}{10} = 9.6^m$
2	15	8.02	11	88.22	
2	12	7.91	11	87.01	
2	12	7.92	11	87.12	
2	11	8.12	11	89.32	$\frac{889.90}{111} = 8.01^M$
2	7	8.14	11	89.54	
2	7	8.12	11	89.32	
2	6	8.04	8	64.32	
2	6	7.98	16	127.68	
−2	5	7.93	10	79.30	
	96		111	888.90	
+0	52	9.08	11	99.88	$T-t\ \frac{577}{10} = 57.7^m$
0	53	9.14	11	100.54	
0	54	8.99	11	98.89	
0	57	9.08	11	99.88	
0	58	9.08	11	99.88	
0	58	9.02	11	99.22	$\frac{993.96}{110} = 9.04^M$
1	0	9.08	11	99.88	
1	0	8.85	11	97.35	
1	2	9.08	11	99.88	
+1	3	8.96	11	98.56	
9	37		110	993.96	

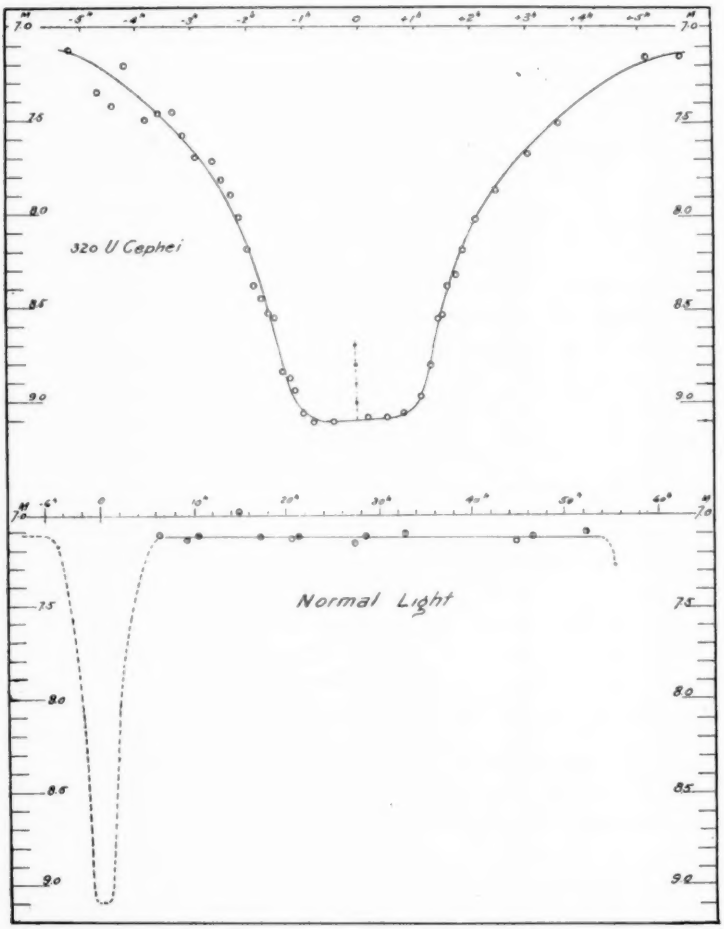
The above examples ought to be self-explanatory. In the last, all the ten observations have the same weight, and the brute mean of the observed magnitude would have been identical with that shown. This, however, would seldom occur in practice.

The normals when computed should be tabulated in order and plotted in exactly the same manner as described for the single light-curve. In the present case there are forty normals in the period of light-change, and fourteen in the interval of normal brightness. To give a table of these would occupy much space for little profit, so I do not give them all.

The accompanying plate shows the curve as plotted, the lower figure showing the normals and curve for the interval of constant light. The curve shows a minimum at -4^m; this is probably an indication that the time assumed as the starting point of the ephemeris may be in error, or that there may be a progressive shortening of the star's period during the time covered by the

observations. In either case it is not important for our present purpose.

The curve having been plotted, we proceed to form a table of readings from it; these readings are taken at regular and equal



time-intervals, short enough to allow of the part of the curve between each two readings to be treated, for the purpose of interpolation, as a straight line. A table of twenty-minute readings from the present curve is here presented.

T—t h	m	Before min. M	After min. M
5	00	7.16	7.18
4	40	7.24	7.26
4	20	7.27	7.34
4	00	7.34	7.42
3	40	7.43	7.49
3	20	7.53	7.58
3	00	7.64	7.67
2	40	7.77	7.75
2	20	7.95	7.86
2	00	8.18	8.03
1	40	8.48	8.29
1	20	8.86	8.68
1	00	9.05	9.02
0	40	9.10	9.06
0	20	9.10	9.08
0	00	9.09	

To show the use of this table in the reduction of observations, we will take four observations from the minimum of U Cephei observed by myself 1902 September 11, taking two from each branch of the curve (in the notes of this minimum thirty-one observations are recorded, of which fully three-quarters are available for such a determination, but four will show the process well enough);

From the decrease.			M	From the increase,			M
8^h	35^m	e4v, v1f	7.92	12^h	8^m	f2v, v3g	8.23
9	0	f3v, v2g	8.34	12	51	e1v, v4f	7.68

For the sake of shortness, I give reduced magnitudes at once.

Taking the first observation, and referring to the table of readings, we find during the star's decrease it reaches the magnitude 7.92m. Between 2^h 40^m and 2^h 20^m before the minimum; the magnitude-interval between these two readings is 0.18, and the indicated T—t is worked out as follows;

	M
-2^h 20^m	7.95
	−7.92
	.03

therefore the time to be *added* to 2^h 20^m in order to find the time of minimum indicated by this observation will be expressed by the proportion

0.10; 0.03: :20^m:x

x standing for the time-value to be so added. Working it out, we find the value of x to be 3.3^m. So that the time of minimum indicated by this observation will be found by adding 2^h 20^m $+3.3^m$ to the recorded time of observation, thus;

	8^h	35^m
	2	20
		3.3
Making the indicated time	10	58.3

Treating the other three observations in the same manner, except that for the two observations from the rising branch, to find the indicated time of minimum, we subtract the interval found from the recorded time of observation, we get the following indicated times;

For	8^h	35^m	10^h	58.3^m
	9	0	10	50.6
	12	8	19	23.4
	12	51	9	57.0
Taking the mean of the four			4) 42	02.3
We have			10	30.8

as the date of minimum deduced from these four observations, corresponding very fairly with the indicated date $10^h\,32^m.4$, found by another method from the same night's observations.

The method by which this value, $10^h\,32^m.2$, was arrived at is called the method of equal brightness, and is considered by some of our best authorities to be the most satisfactory way of determining the date of observed minimum for the Algol-type stars, when both branches of the curve have been observed to a considerable extent; for stars of other types it is in general not available, from the prevailing asymmetry of their light-curves.

The manner of applying this method is as follows; we find from the reduced observations, either graphically or otherwise, the times during the star's decrease and increase when the star arrives at a certain magnitude (or place on the light scale); we take the mean of the two times, and repeat the process at several other magnitudes, not too near together, say two-tenths of a magnitude, or two or three steps apart; being always careful to use only that part of the curve where the light changes are rapid; when we have a series of these means, we find the mean of these, which will be the date of minimum sought.

As an example of the results obtained in actual practice by the three methods of reduction described, I will give here the several deduced times of a minimum of U Cephei, observed by myself on 1895, January 23 and published in No. 355 of the Astronomical Journal.

Time of minimum by Single Curve $9^h\,41^m$
" " " " Mean " 9 33.4
" " " " Equal Brightness;

M	Before	After	Mean
8.6	$7^h\,44^m$	$11^h\,35_m$	$9^h\,40^m$
8.8	8.13	10 55	9 34
9.0	8.26	10 41	9 33
	Mean		9 35.7

The above directions are in no sense exhaustive of the subject; there are many other methods and refinements which have at

various times been used by various observers; the ones given however, are as much as the beginner will be likely to need or be able to employ; and with practice and experience he will find various means suggesting themselves, and will be likely to invent his own ways of working to a considerable extent.

If any one who takes the work up has enough interest in it to find that they desire to know more, the writer will always be glad to afford any assistance or information in his power, and hopes that no one who wants his help will hesitate to ask for it.

Dorchester, 1906, November 3.

REVIEW OF SOLAR OBSERVATIONS FOR THE YEARS 1904 AND 1905 MADE AT ALTA IOWA.

DAVID E. HADDEN

FOR POPULAR ASTRONOMY.

The following results of solar observations are in continuation of those contributed to Popular Astronomy, No 124. The instruments used were the same, viz, a 4-inch refractor and 8½-inch reflector, both by Brashear, with polarizing eyepiece and grating spectroscope.

Owing to the absence from home during the greater part of April and May 1904, the record for those months is rather jejune, only a few occasional observations were secured at irregular intervals.

Reviewing the record for the year 1904 the principal characteristics are:

1. The continued steady increase in the number of groups, spots and faculæ.
2. The entire absence of days without spots.
3. The greater frequency of spots in the northern hemisphere, and,
4. The absence of any groups of the first magnitude.

January 1904. Owing to cloudy weather only ten observations were obtained. Spots were all small until during the last week when a group in southern latitude increased to several large spots before disappearing at the west limb.

February. Only seven groups, all small, were noted this month and but three of these made the entire transit of the disk. An extensive area of faculae near the S.E. limb on the 12th was the seat of active spectroscopic disturbance when it reached the S.W. limb on the 22nd.

March. Spots were small and transient until after the middle of the month when a few larger ones were noted.

April. Absence from home interrupted observations this month. From the 10th to the close of the month, several large spots were visible, but could be seen by me only at intervals.

May. Continued absence from home interfered with work also this month. Spectroscopic observations on the 10th indicated that greater activity was present in some groups in the southern hemisphere.

June. Groups were principally small this month, a fine pyramidal prominence streaked with dark radiating lines was observed at the east limb on 21st.

July. During the first decade spots were small, from 10th to the close of the month larger spots and a more active condition of both hemispheres set in. On the 15th forerunners of a fairly large and active disturbance appeared at the S.E. limb, the immediately surrounding region contained several small but brilliant and active prominences and the H_a line was brightly reversed and distorted. The leader spot underwent many changes during its transit, but before its disappearance at the west limb it assumed the normal single type of spots.

August. A slight increase in the number of groups was noted this month, during the fourth week one group increased to a long stream of small spots.

September was the quietest month of the year, a decided falling off in number of groups and faculae. On many days only single small spots were on the disk.

October. There was a distinct revival of activity this month, several larger spots were observed in both north and south latitudes during the 2nd and 3rd decades. One group increased to a train of some magnitude.

November. Spots were mainly small in first two decades, in last decade a spot increased and before disappearance ranked as a fine spot with numerous umbræ and much spectroscopic activity.

December. Observations were considerably interfered with by cloudy weather. A decided revival of activity again took place this month; during the second decade the disk was well covered with spots, nine distinct groups being noted, containing very many small spots and several large ones.

The following table exhibits the numerical results of the observations for the year 1904.

Months 1904	No. of Observing Days	Average No.of			Average No. Groups		No. of Spotless Days.
		Groups	Spots	Faculæ	N Latitude	S Latitude	
January	10	2.70	13.75	3.14	1.5	1.2	0
February	15	1.73	7.71	2.43	1.1	0.6	0
March	14	3.30	11.21	2.21	2.1	1.2	0
April	11	2.82	9.45	2.70	2.2	0.6	0
May	9	3.78	14.10	3.90	2.0	1.8	0
June	12	3.17	16.75	3.10	1.6	1.4	0
July	21	3.14	17.62	3.20	1.8	1.3	0
August	20	3.85	17.20	3.75	1.8	2.0	0
September	15	1.67	6.73	2.70	0.7	1.0	0
October	13	3.54	16.31	3.54	1.9	1.6	0
November	20	3.30	11.70	3.50	1.4	1.8	0
December	12	4.25	16.50	3.50	2.9	1.3	0

The principal features of the record for the year 1905 are:—

1. The maintained steady increase in number and size of groups, spots and faculae, the per cent of numerical increase being 29, 37 and 24 respectively.

2. The greater frequency of spots in the northern hemisphere which was more marked in the latter half of the year.

3. The appearance of many large spots during the year, one of which during its transit from January 28 to February 10 was of the very first magnitude.

January 1905. The revival of sunspot activity noted in December 1904 continued during this month, some large spots being present during the second decade, but this activity culminated in the greatest solar spot of the present cycle and probably the largest single spot of the last thirty years on the 28th to February 10th. At its ingress at the east limb active spike-like prominences were observed with the spectroscope, and on the following day the region near the east end of the penumbra was very active; brilliant hydrogen jets and sharp diagonal distortions of the H_a line were noted. Owing to intensely cold weather and poor definition the spot could not be very carefully observed after this with the spectroscope.

February. The return of the giant spot which disappeared by rotation on the tenth occurred about the twenty-fourth but broken up into several portions which gradually diminished in size as they approached the west limb; during this second transit the spectroscope indicated considerable activity in the group.

March. During the first week two great groups were visible,—the Jan-Feb group in south latitude already mentioned and another only slightly inferior disturbance which entered the east limb by rotation in the northern hemisphere on March first and during the first week of its advent was an immense intricate mass of penumbra containing several large umbrae and multi-

tudes of smaller nuclei; the spectroscope indicated much disturbance over the entire group; it was much diminished and breaking up as it neared the western limb;

April was a comparatively quieter month, all the spots were smaller and about equally distributed in the N and S hemispheres. The location of the larger March group was the seat of very extensive regions of faculae at the west limb from sixth to eighth.

May. During the first two decades some large spots were observed with interesting umbrae and some spectroscopic evidence of activity in the H_α line. After the disappearance of these spots the disk was entirely free of spots on the twenty-third and twenty-fourth and remained almost quiescent during the remainder of the month, only a few dots being noted.

June. Spots were mainly small during first three weeks. On the twenty-second an equatorial group increased to a larger-sized spot as it approached the western edge.

July, there was a decided renewal of activity this month. During the first decade the S hemisphere was well dotted with spots, and from the eighth to twenty-second some spots of the first magnitude were observed. The largest spot entered the visible disk on the tenth and during its transit it increased greatly in size and many changes took place in the spot as it reached the central meridian, distortions of the H_α line on the fourteenth, and on the sixteenth the umbrae were encircled with brilliant photospheric matter which on the following day seemed to have sundered apart the preceding portion of the spot by a large fissure or bridge; on eighteenth this bridge or gap had disappeared leaving two large umbrae which remained until the spot reached the west limb.

August. The disk was quite well covered with groups during this month, the first week witnessed the return of the two larger July groups which again made the transit of the disk. They were large and interesting, the south one being spectroscopically very agitated in the hydrogen lines, but both groups were much decreased as they neared the western limb.

September. Numerous small spots and trains during the first half of the month and during the closing days.

October. One splendid group of larger size, and two others of lesser magnitude made the transit this month. On eighth to twentieth a fine single type normal spot traversed the visible disk a little north of the equator. This was followed on the thirteenth in nearly the same latitude, by a disturbance only slightly inferior to the giant spots of February and March, it consisted of a

large somewhat branching mass of penumbra with many large umbrae, which was described in my observing notes of the twentieth as a large scorpion-shaped group, branching penumbra and containing over fifty nuclei or umbrae. On the twenty-second it was breaking up, but very active as observed by the spectroscope; after this date it diminished and was greatly reduced when it reached the west limb.

A third equatorial fine group appeared on the twenty-first in south latitude and completed the transit on November second. It had a large elongated umbra which later divided into three parts, bright hydrogen flames were observed on the N. W. edge of this group on the twenty-fifth with the slit of the spectroscope widely opened.

November. The Sun's disk was well spotted all this month, the large spots of October returned by rotation, but all were much smaller in size. Nearly all the spots of the month were in a narrow belt on each side of the equator and during part of the month extended from the west to the east limb in a continuous stream.

December. Spots were mainly small this month. One large group crossed the disk after the middle of the month.

The numerical results for the year 1905 are given in the following table:—

Months 1905	No. of Observing Days	Average No. of			Average No. Groups		No. of Spotless Days
		Groups	Spots	Faculae	N Latitude	S Latitude	
January	11	4.1	15.45	3.6	1 7	2.3	0
February	17	4.8	18.80	4.4	2.4	2.4	0
March	12	3.6	18.30	4.3	2.0	1.6	0
April	12	2.9	11.50	3.7	1.4	1.4	0
May	17	3.2	14.51	4.3	2.1	1.1	2
June	16	3.5	13.88	4.2	1.6	1.8	0
July	24	4.3	21.79	3.8	1.7	2.6	0
August	23	5.0	16.00	4.3	3.5	1.5	0
September	17	3.4	14.00	2.8	2.0	1.2	0
October	20	3.9	24.30	4.0	3.0	0.8	0
November	17	5.8	34.00	3.9	3.8	2.0	0
December	16	3.6	15.60	4.0	1.9	1.8	0

In the subjoined table is given the annual average results for the year 1891 to 1905 for comparison.

Years	No. of Days of Observations	Average Annual Number of			Total No. of Spotless Days
		Groups	Spots	Faculae	
1891	257	2.9	14.9	3.6	24
1892	205	5.6	34.0	4.1	0
1893	177	6.6	36.6	4.1	0
1894	139	5.6	30.0	3.4	0
1895	149	5.2	30.5	3.5	0
1896	197	3.2	17.8	2.9	5
1897	198	2.2	11.0	2.3	29

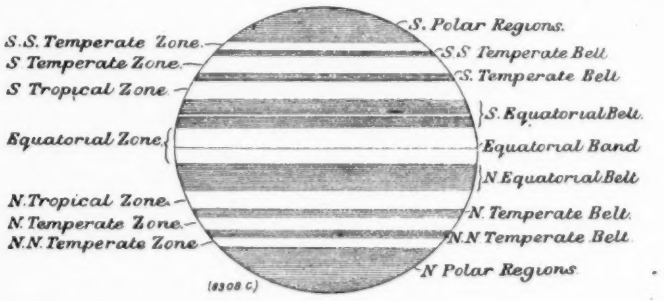
Years	No. of Days of Observations	Average Annual Number of Groups	Spots	Faculae	Total No. of Spotless Days
1898	234	2.1	11.0	2.4	30
1899	259	1.1	4.8	1.5	108
1900	255	0.7	3.4	1.0	134
1901	269	0.25	0.9	0.3	212
1902	230	0.37	2.0	0.5	163
1903	230	1.65	7.8	1.9	32
1904	172	3.10	13.25	3.14	0
1905	202	4.00	18.18	3.9	2

Alta, Iowa.
Nov. 5, 1906.

THE MARKINGS AND THE SATELLITES OF JUPITER.

W. W. PAYNE.

We have been much interested in the recent studies of the markings on the surface of the planet Jupiter, and of the knowledge recently gained of its wonderful system of satellites. For much of the information I shall use in this brief article I am indebted to a report of work done by the members of the British Astronomical Association that compose the so-called Jupiter Section. The scheme adopted by the section for a general description of the surface of the planet, I think, is a good one. Its plan is to use four words to designate various parts of the surface: belt, band, zone and region. Those terms are in common use and they signify well what is meant for the purpose of reference. Each of the belts on the surface of the planet are named so as easily to fix their relative positions in the mind of the observer. The same may be said of the zones and regions. The equatorial



band is a single feature of which scarcely anything is reported from recent observations. We give above a diagram used by the English observers with the nomenclature that belongs to it.

Of course it will be understood by our readers who are not experienced observers of Jupiter, that these markings are not so permanent on the planet as they appear in the diagram; neither are they always equally prominent if fainter. Sometimes the markings are confused and it is difficult if not impossible to trace many of them unless they are on the strong equatorial belt. We have often noticed in the south equatorial belt cloud-like forms in much detail that were beautiful when viewed in a 16-inch telescope. In this respect this belt is more interesting than its mate on the north side of the equatorial band. It is also to be remembered that the great red spot on the planet is adjacent to, and even crowds into, this great southern belt. At the time of the discovery of the red spot in 1878 and for some time after, it was so far south of the belt that it was entirely clear of it. At least that was the appearance of the relation of the two markings.

By looking at Mr Denning's drawings it is seen that the red spot has crowded its way deeply into this strong southern belt and quite severed it at the northern point of contact. This relation of these two phenomena that has been going on for twenty years, in slow change is a most interesting fact in regard to the surface condition of the planet.

The great red spot has shown considerable variation in its rotation period during the last few years. In 1901 its period was $9^h\ 55^m\ 40^s.63$. "In 1902 the motion was accelerated and this was especially noticeable during the time that the dark matter of the great south tropical disturbance was sweeping round it. In 1903 a retardation set in, and the longitude of the 'hollow' increased from about 31° at the end of June to about 35° in January 1904. In the early summer of 1904 the south tropical disturbance for the second time came into conjunction with the red spot, and again a decided acceleration in the latter was noted, the increased velocity apparently persisting until the end of September."

As the English observers say, "it is not absolutely certain that the acceleration exhibited by the red spot in 1902 and 1904 is due to the conjunction of the south tropical disturbance, but it is at least significant that the two phenomena should have coincided in both years." We will look with interest for a report on the motion of the red spot at the conjunction of the south tropical disturbance that was expected to take place in July 1906.

We have been much interested in the study of the white spots on the belts and bands of the planet. These markings appear to be in motion, and may also be disturbances, but no one dares

to say what is the cause of them. If the cause is similar to that of the red spot, it would be helpful possibly to know why in one the surface is a reddish brown, and in the other nearly white. It seems pretty certain that the surface of the great planet must be in a tempestuous state, more or less constantly, from what we can see if our inferences are worth anything.

The great variety of detail in the study of the surface markings of the planet Jupiter that the English observers are steadily gathering, by their systematic way of working, and their careful and painstaking way of publishing their results must be useful in finding new facts to help our knowledge of Jupiter which is so deficient in many important ways.

We copy two of Mr. W. F. Denning's drawings which are the latest we have seen of his excellent work. They show plainly some of the points of reference to the surface markings of the planet to which reference has already been made.

The system of satellites belonging to Jupiter has come to be one of considerable interest in many ways, some of which we will briefly specify.

Observations of the eclipses of these satellites for a long time has been made for the purpose of securing data for the nautical

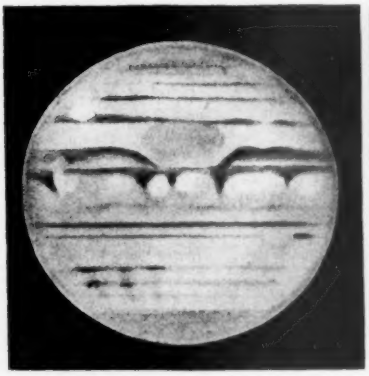


FIG. 1.—W. F. Denning, 10-in. Spec. 1903, July $1^d\ 16^h\ 7^m$ G. M. T. $\lambda=38^\circ$ (System I), 32° (System II).

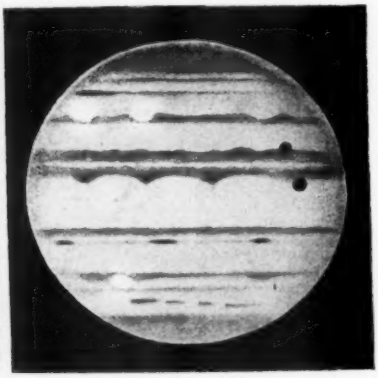


FIG. 2.—W. F. Denning, 10-in. Spec. 1903, Aug. $7^d\ 13^h\ 45^m$ G. M. T. $\lambda=37^\circ$ (System I), 109° (System II).

almanac to verify its predictions of their respective places at any given time, and also for the purpose of determining longitude whenever such a method may be necessary. The defect in the visual observation of an eclipse is that its circumstances with different ob-

servers is very likely to vary—better say it is certain to vary—for observers usually have telescopes that differ, their powers of sight differ, atmospheric conditions in different places are not the same. It must be evident that the penetrating power of different telescopes would follow a satellite into the shadow of the planet differently, so that the times of the actual disappearance of the satellite in the two telescopes would not be the same. In the same way, the other disturbing factors would designate different times of eclipse in different places and, for the same reason, at different times for the same place.

As a partial remedy, in some of these particulars, some observers have given more attention to this theme and have used photometers as the means of determining the times of eclipses of the satellites by the way those instruments work. Another source of error in estimating the time of eclipse is due to variability of the light of some of the satellites of this planet. If the light of the satellite is variable, it is the custom of the English observers, I think, to use the light curve belonging to the particular satellite and in that way correct errors that might arise on this account, in estimating the time of eclipse. Any good, systematic way of observing the times of the eclipses of Jupiter's satellites by individual observers with telescopes that are securely mounted, so that they will be steady enough for such observation will prove interesting and useful work, even though the telescope has a clear aperture of not more than four or five inches. Such instruments will work well on the larger satellites, but of course they will not reach the fainter ones.

The Harvard plan is to use the meridian photometer, and the brightness of the fading satellite is compared at intervals of a few seconds with that of uneclipsed satellites. Some English observers think that the wedge photometer is simpler and that it will give good reults. The way the wedge is used is to set it so that the light of the fading satellite can be seen and then note by the motion of the wedge what is the reading when the light of the satellite is effaced. Repeat this process several times, and from the data secured draw the curve that will show how the light of the satellite changed during the time of its fading to the point of totality. This is a simple method and it could be applied to all the satellites that can be observed, in transit, in occultation and in eclipse. Of course observers will say we can not do much with the photometers in occultations of satellites for that phenomenon is an instantaneous one. One reason why we include occultations is that some very singular phenomena occur at the

time of occultations. Here is a remarkable one observed by Mr. Gale of England and noted on page 90 of the report we are now considering. On November 13, 1903, Satellite III was to disappear between $21^h\ 17^m\ 7^s$ and $21^h\ 23^m\ 54^s$. What Mr. Gale reports is that he saw this "satellite visible through the limb." In explaining this remarkable statement, he himself says "Most remarkable! The satellite was visible through the limb. The bright spot within the limb was visible at $21^h\ 22^m\ 50^s$, while a small arc brilliantly illuminated was still outside. The complete circular spot wholly within the limb was visible for 33 seconds after internal contact was noted. At first it was like a satellite in transit, but somewhat fainter than usual. The thought occurred to me that I had mistaken the almanac, but the position on the limb at once corrected the idea.

I have observed many dozens of occultations, but never have seen an appearance of this sort before." He adds that the limb, at the time was sharp and steady, and the latitude that of the bright strip included the two components of the double N temperature belt.

Another English observer while watching this III satellite of Jupiter as it disappeared by occultation, November 6, 1904, noted first contact at $10^h\ 11^m$; "satellite appears to lie in hollow of limb $10^h\ 11^m$; it is bisected at $10^h\ 17^m$ and appears either on disk or through it; at $10^h\ 19^m$ satellite seems to disappear and reappear; at $10^h\ 20^m$ satellite gone." Such observations are remarkable and extremely curious. It has occurred to us, that an observer practiced in handling the photometer, might, in some of these cases, get the light curves of change, and in that way throw some light on the cause of the singular behavior of this satellite.

We have not now the space to speak particularly about the relative brightness of the larger satellites belonging to Jupiter, except to say that they differ among themselves considerably in this respect. The word that astronomers commonly use to designate this fact is albedo. Our readers, generally already know probably, that the word albedo when applied to the light of a planet or a satellite means the condition of surface which determines its reflecting power. For example, if the light of the Sun falling on the planet Mars should be called 100, and that which should be reflected from its surface was 22, then we would say the albedo of Mars is 22. If the amount of the incident light is taken as unity, then the albedo of Mars would be 0.22. That value for the albedo of Mars is now recognized as nearly the true one. It is a strange fact that the surface of Mars has such high

absorbing power that it can reflect only about one-fifth of the light that goes to it from the Sun. Stranger still if we think of our own bright Moon as being able to reflect only 0.17 while the planet Mercury falls still lower in the scale, for its reflecting power is only 0.14. It is very different with Venus, Jupiter and Saturn. Their surfaces reflect respectively 0.76, 0.62 and 0.72.

The work that is now being done in regard to relative brightness, color, surface markings and variabitity of these satellites is very considerable and highly interesting.

But the feature of recent study of the satellites of Jupiter's system that claims special attention is the discovery of new satellites that belong to his family. In this field, Mr. C.D. Perrine of Lick Observatory, Mount Hamilton, California, has done remarkable work. January 5, 1905 the first discovery was made, but it was found that the same object appeared on photographic plates taken with the Crossley reflector on December 8, 9 and 10 previously. At first the astronomers of Lick Observatory were in doubt as to the real nature of the object so photographed. On further examination of plates taken January 2, 3 and 4, it became apparent that another satellite had been recorded, much fainter than the one already discovered. The last object was rated as low as a 16th magnitude star. If this estimate is right, one can easily think what that means in the line of photographic work. It is truly astonishing. It is in the region of the doubtful and very near to the impossible when one thinks how very faint a 16th magnitude star is. Theoretically a 17th magnitude star can be seen visually in the 36-inch refractor. It is indeed at the limit of a telescope whose object-glass is about 40 inches in clear aperture.

In saying this we do not mean to indicate that there is now any doubt about the wonderful discoveries of Satellites VI and VII, made by Mr. Perrine by the aid of photography while using the Crossley reflector, but rather to call attention again to that noble piece of work and the instrumental means by which it was accomplished.

The announcement of this last discovery was held back for nearly two months because of the uncertainty of the motion of the object. It was difficult to tell whether the object was a satellite or not, and also whether its motion, if a satellite, was direct or retrograde. These difficulties will be understood partly at least, when one thinks of the orbits of these two new satellites as very peculiar indeed when compared with those of the others. The new orbits are very distant from Jupiter—over seven millions of miles. Barnard's Vth satellite is only 112,500 from

the planet. The farthest one of the old satellites is 1,167,000 miles from the planet. If, then, one should go out into space from Jupiter about seven times as far as the last named one, he would reach the paths of the two new very faint satellites.

Another interesting fact about these new orbits is that they resemble each other closely in some respects. Both are about the same distance from the planet, both have large inclination to the plane of Jupiter's orbit, (about 30°), the VIIth has great eccentricity, and it is thought by some astronomers that their two paths intersect each other. One can scarcely keep back the suggestion that these two satellites may be somehow related to each other, from the fact that they have so many features in common.

We had hoped to find data enough to construct the orbits of these new satellites and thus to show the graphical relation between the planet and its entire system of satellites. But, so far as we know, definition on the new orbits has not yet gone far enough to give us the data desired.

SIGNIFICANCE OF THE SPIRAL NEBULAE.

T. J. J. SEE.

FOR POPULAR ASTRONOMY.

In the October number of *Popular Astronomy* your readers are presented with the thoughtful address of M. Poincaré on the Milky Way and the Theory of Gases, which contains very sagacious suggestions regarding the spiral nebulæ. From the trend of his remarks (pp. 484-487) it is clear that M. Poincaré considers that the spiral nebulæ are most probably other Milky Ways, and he cites Stratanoff's work on our own Milky Way as confirming this view. Poincaré's remarks are extremely suggestive and worthy of the most careful attention.

For a number of years the writer has given consideration to the probable nature of the spiral nebulæ, and their importance has been considerably increased by photographs obtained by Roberts and Keeler, and more recently at the Yerkes Observatory. Certain speculations have been indulged in which implied that the spiral nebulæ are true nebulæ condensing into systems of stars. Though this premature and unauthorized line of thought has been extensively exploited, and even given place in one treatise on Geology, it has always seemed to the writer quite unsound. I have consistently held that so far we do not know the true character of the spiral nebulæ, and this position is amply

justified by the penetrating remarks of M. Poincaré. Whether the spiral nebulæ are other Milky Ways, as suggested by the illustrious French geometer, time alone can tell; and it may be several centuries before this question can be satisfactorily settled. Meanwhile the exploitation of the spiral form as typical of nebular development is certainly misleading, for, as Poincaré points out, there is no proof that these spirals are true gaseous nebulæ.

Moreover, in *Popular Astronomy*, no. 100, the writer has shown that we have no proof as yet that the nebulæ really form the stars. The large part played by repulsive forces in nature requires us to be very cautious in concluding that masses of such great extent and irregularity of figure are really condensing. The whole outline suggests repulsion from centers rather than condensation; and such a view is also in harmony with recent investigations of radio-active and other repulsive forces, in the study of which only a beginning has been made.

If we do not know that the nebulæ form the stars, we certainly are not justified in assuming that spiral nebulæ represent a type of stellar evolution, and all such speculations are vague and worthless.

The recent suggestions that the spiral nebulæ, on account of the double ansae which occasionally project from them, give evidence of tidal disruptions, produced by the passage of some neighboring body, it is needless to say are not only gratuitous, but unjustifiable and in the highest degree improbable. I am not one of those who desire to restrict the domain of speculation, but to be of real value a speculation must rest on a *vera causa*, and not assume improbable conditions. The speculations on spiral nebulæ have been decidedly overdone, and it is time to call a halt. There is not the slightest probability that our solar system was ever a part of a spiral nebula, and such a suggestion is simply misleading and mischievous. The great circularity of the planetary orbits shows the absurdity of such an hypothesis, and this leading characteristic of our system as bearing on its mode of origin was carefully considered by Laplace more than a century ago.

At present we must frankly admit that the nature of the spiral nebulæ is quite unknown. And while we cannot be sure that nebulæ develop into stars, we may justly hold that the stars are the outgrowth of gravitational condensation of matter which was once dark.

The closeness of most revolving double stars seems to indicate that separation takes place in the stellar rather than the nebular

stage, and this leads us to doubt whether the forms of the nebulæ can be expected to disclose the processes of stellar evolution. Least of all can we expect any light from the much exploited spiral nebulæ, which as M. Poincaré justly remarks, may be other Galaxies. It is time therefore to drop such spirals from our text books, or to candidly admit that we are quite in the dark as to their true significance.

Naval Observatory,
Mare Island, California.
October 23, 1906.

ON THE ANCIENT ECLIPSES OF THE SUN.*

E. NEVILL.

It was with much interest that I read Mr. Cowell's recent papers on the ancient eclipses of the Sun, and the values they indicate for the secular accelerations of the longitudes of the Sun, Moon and lunar node, and it is with some curiosity that I have waited for the last six months to see if any of the distinguished astronomers conversant with the subject would critically examine the results which Mr. Cowell has deduced.

In the first of these papers (*Monthly Notices*, vol. lxv. p. 861) Mr. Cowell reaches the conclusion that if the Moon's secular acceleration be taken as $+7''.0$, in order to represent the ancient eclipses of the Sun it is necessary to reduce to about $+4''.4$ the secular acceleration of the Moon's angular distance from its node, corresponding to a reduction of the secular acceleration of the Moon's node to only a third of its theoretical value.

In the second of these papers (*Monthly Notices*, vol. lxvi. p. 3) Mr. Cowell points out that, as this reduction of the Moon's nodical secular acceleration is inconsistent with the theory of gravitation, the requisite value of the secular acceleration of the Moon's angular distance from its node should be obtained by adopting the theoretical value of the secular acceleration of the node and increasing the secular acceleration of the Moon's mean longitude from $+6''.8$ to $+10''.9$, and ascribing a secular acceleration of $+4''.1$ to the mean longitude of the Earth, so as to leave unchanged the epoch of conjunction of the Sun and Moon in mean longitude.

The results deduced in these two papers are quite distinct, and

* MONTHLY NOTICES, May, 1906.

form two questions which may well be examined separately.

The first is the existence of an apparent secular acceleration of $+4''.4$ in the angular distance of the Moon from its node.

The records of the ancient eclipses of the Sun and the values they indicate for the secular accelerations of the Moon's mean longitude, longitude of node, and longitude of perigee have been examined in some detail in one of the sections of my unpublished memoir on the errors of the lunar tables, and from it can be derived further information on the subject considered in Mr. Cowell's papers.

The eclipses are referred to Hansen's *Tables du Soleil* and to Hansen's *Tables de la Lune* under the following forms:—

A. Hansen's Tables, with his final values for the secular accelerations and motion of the node.

B. Hansen's Tables, after replacing his tabular values of the secular accelerations by those derived theoretically from the secular diminution of the eccentricity of the terrestrial orbit and making the small consequent corrections necessary to bring the amended tables into accord with the modern observations.

C. Hansen's tables, after applying the corrections indicated by a complete discussion of the lunar observations between the years 1650 and 1900, employing for the secular acceleration of the mean longitude the value $+7''.43$, of the longitude of the node the value $+6''.07$, and of the longitude of the perigee the value $-32''.53$.

The only eclipses considered are those at least two thousand years prior to the present epoch, as these of later date are of little real value for the desired purpose.

In the following $\Delta\phi$ represents the distance of the central line of totality from the assumed place of observation, measured on the meridian in degrees of latitude, a positive sign showing that the central line of totality is to the south of the assumed place of observation.

I. *The Eclipse of Agathocles.*—Recorded as having happened on—309 August 14, on the second day after Agathocles had left Syracuse on his way by sea towards Carthage. It being unknown whether he sailed south or north of Sicily, it is uncertain whether the eclipse was observed from $36\frac{1}{2}°$ or from $38°$ N. latitude, in both cases the longitude being about $15°$ E. The different modifications of the lunar tables yield the following values of $\Delta\phi$ measured from the latitude of Syracuse ($37°$ N.), and to them has been now added the value that has been obtained from Mr. Cowell's data by an approximate calculation:

A = + 1°.8 B = + 0°.8 C = + 0°.8 Cowell = − 0°.0

As the width of the zone of totality exceeds two degrees, it is apparent that the eclipse is represented by all four systems of data.

II. *The Eclipse of Pelopidas.* A very large, but not necessarily total, eclipse of the Sun, said by Plutarch to have occurred before Pelopidas left Thebes on the expedition against Alexander of Pheræ. Apparently it must have been the eclipse of −363 July 13. The values of $\Delta\phi$ are

A = + 10°.8 B + − 11°.8 C = − 11°.5 Cowell = − 16°.0

These all indicate a large eclipse, but the results are of little use.

III. *The Eclipse of Ennius.*—Stated by Cicero to have occurred at Rome in −399 June 21 toward sunset. It appears doubtful if the Sun was totally eclipsed before sunset, or even if it were total at all. If there had been any certainty on this point it would have been a most valuable criterion, and deserved the great weight assigned it by Hansen. The values of $\Delta\phi$ are

A = − 1°.2 B = + 10°.4 C = + 7°.4 Cowell = + 3°.1

According to Hansen's values the Sun set after totality; but according to the modified forms it must have set some time before totality, and the eclipse cannot have been total near Rome.

IV. *The Eclipse of Lysander.*—Stated by Xenophon to have occurred in the autumn of the year that Lysander took Athens, which would correspond to the eclipse of −403 September 3. It must have been a large eclipse, but not necessarily a total eclipse in Greece. The values of $\Delta\phi$ are

A = − 0°.2 B = + 2°.6 C = + 1°.6 Cowell = − 2°.4

The eclipse was annular, and according to all four sets of data must have been very large at Athens.

V. *The Eclipse of Thucydides.*—Stated by Thucydides to have occurred in the summer of the first year of the Peloponnesian War, and to have been nearly, but not quite, total at some spot in Greece— probably Athens, but quite possibly some place in the northern Ægean Sea, or even in the Ionian. It is this uncertainty which weakens the value of this eclipse as a test. The eclipse was only annular, and occurred so soon before sunset that stars might have been seen as recorded, even had the eclipse been only a large eclipse. The values of $\Delta\phi$ are:

A = − 17°.8 B = − 1°.8 C = − 5°.8 Cowell = + 0°.1

Hansen's values fail to account for this eclipse; both the theoretical secular accelerations and Mr. Cowell's data represent it as seen at Athens, and the data C as if seen from the northern Ægean.

VI. *The Eclipse of Thales.*—Stated by Herodotus to have occurred during a battle, fought probably at some place in Asia

Minor, between the Lydians under Alyattes and the Medes under Cyaxares, at the end of a war of some length, during the period when Labynetus was king of Babylon. This war must have happened after the destruction of the Assyrian Empire by the Medes and Babylonians, and so have been later than the year—600. According to both Herodotus and Pliny, it was the eclipse predicted to the Ionians by Thales, and the date assigned by Pliny corresponds with that of—584 May 28.

There exist no means of ascertaining the position of the battle-field, and all that can be assured is that in all probability it was some spot on the great road from the Cilician Gates, through Iconium, to Sardis; though there is always the possibility that it was on the northern road by which Cyrus subsequently invaded Lydia, which passed by Pteria, in Northern Cappadocia.

Airy, Hind, and Hansen identify this eclipse with that of —584 May 28, which according to Hansen's Tables, crossed Southern Asia Minor; and it is difficult to reconcile the existing accounts with any other eclipse. It is true that recent investigation has shown that the data assumed in Hansen's Tables require such modification that the zone of totality of the eclipse of—609 September 28 may have passed over the north of Asia Minor, crossing the northern route afterwards followed by Cyrus; but as this eclipse happened before the fall of the Assyrian Empire it must have occurred prior to the war between the Medes and Lydians. Similar permissible changes in the data of Hansen's Tables show that the zone of totality of the eclipse of —556 May 17 may also have crossed the southern portion of Asia Minor, traversing the southern route from the Cilician Gates to Sardis, upon which the battle was fought in all probability; but if this eclipse be assumed, Crœsus could not have succeeded Alyattes until after —556, and it is difficult to compress the events of his reign into the ten years between that date and the capture of Sardis by Cyrus in about —545. Yet it is difficult to reconcile the earlier date of the eclipse with the statement of Herodotus that Labynetus was king of Babylon both at the epoch of the eclipse and at the capture of Sardis by Cyrus, as Nabu-kudur-nzur (Nabuchadrezzar II), who reigned in Babylon in —584, died in —561; but if the later eclipse were adopted, then the king of Babylon at both events may have been Nabu-nahid (Nabonidus), who reigned from —556 to —537.

The values for $\Delta\phi$ for the eclipse of —584 May 28, measuring from Iconium, are

$$A = -2°.0 \quad B = +3°.1 \quad C = +1°.1 \quad \text{Cowell} = -3°.0$$

and as the zone of totality considerably exceeded two degrees in width, all four sets of data will serve to bring the phase of totality within permissible limits of latitude. But according to the different data, totality is reached at sunset at east longitudes:

$$A = 44° \qquad B = 23° \qquad C = 29° \qquad \text{Cowell} = 29°$$

and as the probable longitude of the battlefield lies between 30° and 32°, except in the case of Hansen's data, the Sun must have set before the eclipse was total, though in all cases it would have been very largely eclipsed before reaching the western horizon.

Would this suffice to meet the exigencies of the account given by Herodotus?

The values of $\Delta\phi$ for the eclipse of −556 May 19 are

$$A = -5°.0 \qquad B = +2°.7 \qquad C = +1°.0 \qquad \text{Cowell} = +5°.0$$

and the zone of totality is narrow, little exceeding half a degree. The Sun in all cases would at totality be well above the western horizon; and according to the data C, and possibly B, it would cross the probable position of the field of battle. Apart from chronological difficulties, this eclipse seems to agree with the account given by Herodotus even better than the earlier one. To throw over the circumstantial account given by Herodotus on the ground that he was credulous and related fables does not seem sound; and it must be remembered that recent discoveries have generally confirmed the accuracy of Herodotus, even when his accounts seemed most improbable to earlier critics.

VII. *The Eclipse of Larissa.*—According to Xenophon this eclipse occurred at the capture of the "Median" city of Larissa by the "Persians"; and, from the account of its effects, it must have been a total eclipse to have spread such consternation amongst the defenders of the city that they fled from the walls. The ruins of Larissa seen by Xenophon have been identified with certainty with the mounds of Nimrud, covering the remains of the Assyrian city of Calah. As the Sun represented Asshur, the ruling deity of Assyria, its eclipse would account for the terror of the defenders of Calah, who would take the darkness overspreading the Sun as indicating that the gods had decreed the ruin of Assyria.

With the imperfect knowledge of Assyrian chronology then alone available to guide him, Airy was led, in 1856, to identify this eclipse with that of −556 May 19, and showed that, according to Hansen's Tables, the narrow zone of totality passed nearly centrally over Larissa, and that there was no other eclipse within a period of forty years which could have been total at Larissa. But this eclipse cannot be reconciled with the theoretical value

of the secular acceleration of the Moon's longitude, and it has proved the great obstacle to any reduction of Hansen's tabular values of the accelerations to the smaller values indicated by modern observations, as well as by theory, because any such reduction must throw the zone of totality of this eclipse many hundreds of miles to the south of Larissa.

Professor Newcomb, and others seem disposed to evade the difficulty by either ignoring the eclipse, throwing over the tradition as unfounded, or ascribing the cause to some extraordinary meteorological phenomenon, and not to an eclipse of the Sun. I do not think this can be justified, and can see no reason for disbelieving the traditional account, which is so much in harmony with what is known of the Assyrian character; all the more so as the whole course of recent discovery has tended to confirm the accuracy of these traditional records of the events of ancient history.

As the eclipse of —556 May 19 cannot be reconciled with the value of the secular acceleration indicated both by theory and by the modern observations of the Moon, it is certain that it cannot be the eclipse which occurred at the capture of Larissa.

Since the epoch of Airy's identification of this eclipse much progress has been made in our knowledge of Assyrian history and chronology, and the actual dates of the greater part of the known history of Assyria have been determined with certainty; but, often as this eclipse has been discussed since Airy's memoir of 1857, it does not seem to have been noticed that the capture of Larissa, the Assyrian city of Calah, by either Medes or Persians cannot possibly have taken place in —556. Nineveh, Calah, and the other great cities of Assyria disappear from history before —600, and no reference to the existence of these great cities is known to occur at any subsequent period, either in Babylonian, Persian, Egyptian, or Grecian records. They were all destroyed together during the great invasion prior to —600, and the very state of the ruins at the present time shows that the destruction was sudden and once for all. Every inhabitant perished or was transported in slavery to some distant spot, and the cities were never allowed to be re-inhabited. The capture of Larissa to which the tradition refers must be the capture of the Assyrian Calah by the Medes and Babylonians prior to —600, and could not refer to the capture by the Persians of a town built by the Medes on the site of the older Assyrian city of Calah, a town of whose existence there is no record, and of whose remains there is no sign amongst the existing ruins of

Calah. As before remarked, the very state of the ruins shows that Calah was an Assyrian city when destroyed prior to —600, and that its destruction was final.*

The great seige of Nineveh began in —608, and after a long seige ended with the destruction of the city in —605. Were the surrounding cities of Calah, Dur-Sargina, &c., besieged and captured before or after the capital, Nineveh? The whole tenor of ancient history shows that they would be besieged and taken one after the other, and not all at once. If Calah was besieged and taken before Nineveh, then the eclipse must have been that of —609 September 30. If besieged and captured after Nineveh had fallen, then the eclipse must have been that of —602 May 18.†

The values of $\Delta\phi$ for these two eclipses are:

—602 May 18	A = + 12.°0	B = + 0.°2	C = + 2.°0	Cowell + — 0.°6
—609 Sept. 30	= — 9.7	= — 1.2	= — 3.4	= —8.9

* Even if it had been permissible to suppose that the Medes, after capturing and destroying the city of Calah, had refounded a Median town on the site though a supposition inconsistent both with history and with the state of the ruins, and that it was the capture by the Persians of this hypothetical new town of the Medes, to which the tradition referred, still even this would not save the eclipse of —556 May 19. For just as it is certain that the capture of the Assyrian city of Calah by the Medes and Babylonians occurred nearly half a century before this eclipse of —556 May 19, so it is equally certain that Cyrus, King of Ansan and Persia did not revolt against the Medes until the sixth year of Nabunahid (Nabonidus), King of Babylon, which corresponds with —448, eight years after the eclipse, and did not attack this region until the invasion of Babylonia in — 538.

† It is known that the great palace of Calah was burnt down from some cause and rebuilt by Assur-bani-pal's successor, Assur-etil-ilani, some time between —620 and —615. It has been assumed that this burning took place during the Scythian (or Mandaian) invasion, which occurred about the time of Assur-bani-pal's death in —625. This assumed capture of Calah, and of Calah only, out of all the surrounding cities, by the Scythians about —625 does not harmonize with the rest of the events of this period, nor even with the probability. The very fact that an attempt was made to rebuild the place, though in an inferior style, by Assur-bani-pal's successor, Assur-etil-ilani, would strongly indicate that the place was destroyed by an accidental fire, similar to that which happened nearly three centuries before. If the city had been captured and burnt with the palace at this earlier epoch, it is not likely that an attempt would have been made to re-erect an inferior building amongst the ruins of a destroyed city when the king had so many other magnificent palaces in the surrounding cities. But if the palace of the second city of Assyria had been accidentally burnt, leaving the great city in existence, then it is probable enough that an attempt should have been made to restore the palace accidentally destroyed, though even in an inferior style, rather than leave the ancient capital of Assyria without any residence for the king. Certainly no attempt was made to restore any of the other palaces when once they had been destroyed with the surrounding cities during the conquest by the Medes and Babylonians.

The zone of totality of these eclipses was wide in each case, and both occurred near midday. Neither eclipse can have been total at Calah, according to Hansen's data; but the eclipse of —602 May 18 was total on all three other systems of data, and the eclipse of —609 September 30 was total according to the theoretical values of the secular acceleration. This great obstacle to the adoption of the theoretical value of the secular acceleration vanishes.

VIII. *The Eclipse of Archilochus.*—Described by Archilochus in one of his poems, and from the description must have occurred at midday and been at least annular, but probably total, where it was seen. Beyond this everything is vague. It may have been any eclipse of this nature between —710 and —640; and though probably observed at Thasos, may have been seen from Paros, or even from some other place on the Ægean Sea. The eclipses during this period which it might have been are those occuring on

—710	March	14	Total
—703	October	19	Annular
—688	January	11	Annular
—656	April	15	Total
—650	June	7	Annular
—647	April	6	Total
—640	November	11	Annular

Mr. Cowell, like Professor Millosevich, selects the eclipse of —647 April 6 because it agrees with the data he adopts; but this is considerably later than the date usually assigned to this poet. Still as pointed out by Mr. Lynn, Archilochus has referred to the capture of Magnesia by the Cimmerians, which took place during the reign of Assur-bani-pal of Assyria, and so must be later than —668, but probably before —660, the beginning of the trouble with Elam. The values for $\Delta\phi$ for these eclipses, supposed seen from Thasos, are:

—710 March 14	A = + 8.°1	B = — 10.°7	C = — 8.°6	Cowell = ...
—703 Oct. 19	— 7.3	+ 2.7	— 0.7	
—688 Jan. 11	+ 13.6	+ 6.3	+ 7.9	— 1.8
—656 April 15	+ 16.1	— 2.0	+ 0.7	
—650 June 7	— 8.8	— 8.2	— 8.2	
—647 April 6	+ 0.3	— 12.9	— 9.6	+ 0.5
—640 Nov. 11	— 25.4	— 7.0	— 12.5	

From this it appears that the eclipse of Archilochus may be represented on the data A by assuming it to be the eclipse of —647 April 6, as seen from Thasos; on the data B, employing the theoretical accelerations, by assuming it to be the eclipse of —656 April 15 as seen from Thasos or the eclipse of —703 October 19 as seen from Paros; on the data C by assuming it to have been either the eclipse of —703 October 19 or that of —656 April 15, as seen

from Thasos; or by Mr. Cowell's data by supposing, as he does, that it was the eclipse of —647 April 6, as seen from Thasos, or the eclipse of —688 January 11.

It is apparent that this eclipse can afford no information as to the true values of the secular accelerations, as none of these seven eclipses, seen from either Thasos or Paros, can be found which will harmonize with any permissible values.

IX. *The Eclipse of Susa.*—Recorded in a tablet of the reign of Assur-bani-pal, immediately before his expedition against Elam in —659: "Te umman devised evil, and Sin devised against him forebodings of evil. In Tammuz an eclipse at evening. He troubled the lord of light, and the setting Sun thus also for three days was troubled. It went forth for the end of the reign of Elam." An eclipse of the Sun could not trouble the Sun for three days, but Dr. Pinches considers that the eclipse and the troubling of the Sun should be regarded as distinct occurrences. Even were there objections to so differencing them, the record may be interpreted as reading that the Sun was so troubled or eclipsed "*on*" three days, or that there had been three eclipses, probably at sunset.

The inscription does not say that the eclipse was total; a large eclipse at sunset would suffice; but the month, Tammuz, of the specified eclipse is only consistent with the eclipse of —660 June 27. The values of $\Delta\phi$ are:

$$A = +1°.6 \quad B = +13°.5 \quad C = +7°.9 \quad \text{Cowell} = +6°.0$$

All occurred near sunset. According to Hansen's data it would have been annular before sunset; but, according to the data C and those adopted by Mr. Cowell, only a large partial eclipse at sunset, whilst the system depending on the purely theoretical data would make it a much smaller eclipse. There are two other eclipses at this time; one, that of —661 January 12, would have been a large eclipse at sunset; and another, in —663, would also have been visible, but not at sunset.

X. *The Eclipse of Esar-haddon.*—Recorded in the form, "Since my lord went to Egypt an eclipse has taken place in the month of Tammuz" (June), on an Assyrian tablet of the reign of Essar-haddon, between —680 and —668. The only large eclipse which can answer to this description is that which occurred on —678 June 17. There is absolutely no other in the reign of this king which it could have been. Yet this eclipse occurred several years before Essar-haddon's great Egyptian wars; and, if it be the eclipse of this date, the statement that it occurred when the king had gone to Egypt must refer to one of the early expeditions to

the frontiers of the empire, which are only imperfectly recorded in the early annals of this king of Assyria.

The values of $\Delta\phi$ are:

$$A = +19^{\circ}.6 \quad B = +5^{\circ}.6 \quad C = +11^{\circ}.3 \quad \text{Cowell} = +4^{\circ}.8$$

It will be seen that this eclipse would have been a very large eclipse at Nineveh according to the data employed by Mr. Cowell, or those depending on the theoretical secular accelerations.

XI. *The Eclipse of Nineveh.*—Recorded under the form "Eponomy of Bur-Sagall, Governor of Gozan. A revolt in Assur took place in the month Sivan, and the Sun was eclipsed" on an Assyrian cuneiform tablet as occurring in the eighth year of Assurdan III., corresponding to —762. Hence the eclipse must have been that of —762 June 15. It will be seen that the eclipse is not stated to have been total, nor is anything recorded indicating that it was total; and though undoubtedly it must have been large, it must not be assumed to be necessarily a total eclipse, as assumed by Mr. Cowell. In consequence it is not of great value for ascertaining the probable amount of the secular accelerations, though highly important as fixing Assyrian chronology.

The values of $\Delta\phi$ are:

$$A = -4^{\circ}.1 \quad B = -6^{\circ}.7 \quad C = -5^{\circ}.9 \quad \text{Cowell} = -0^{\circ}.8$$

As the zone of totality was fairly wide, Mr. Cowell's data make it total at Nineveh, but on the other systems it is only very large, Either would satisfy the record.

These eclipses are considered in my memoir, and to them may be added the new eclipse recorded in the Babylonian tablet deciphered by Mr. King and quoted in part by Mr. Cowell.

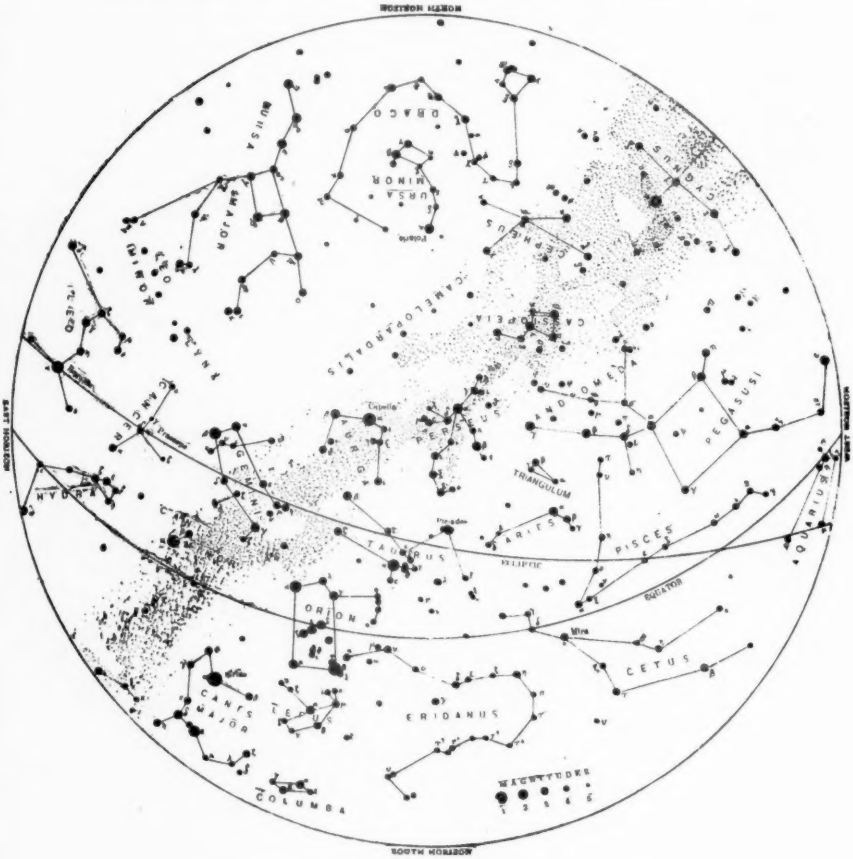
To be Continued.

PLANET NOTES FOR JANUARY, 1907.

H. C. WILSON.

Mercury is passing around to the farther side of the Sun and will reach superior conjunction February 2. It will therefore be invisible to the eye during January.

Venus as morning star will attain her greatest brilliancy on January 4. She



THE CONSTELLATIONS AT 9 P. M. JANUARY 1, 1997.

will be at perihelion on January 7. The phase of Venus is crescent increasing from 0.23 January 1 to 0.45 January 31.

Mars is near the meridian at seven o'clock in the morning in the constellation Libra and so may be seen from three to six a.m. The planet's disk is too small

yet for study of the surface markings the apparent diameter being only 6″ toward the end of the month.

Jupiter has just passed the point opposite to the Sun and so is in splendid position for observation. The planet is in the constellation Gemini, seen toward the east in the early evening and ascending well toward the zenith at midnight, and exceeds any of the stars in that part of the sky in brightness.

Saturn may be seen toward the southwest in the early part of the night and may be studied in the evening twilight.

Uranus is behind the Sun and so cannot be seen during this month.

Neptune will be at opposition on the night of January 2. It may be found with the aid of a large telescope in the constellation Gemini, about a degree south and six degrees east from Jupiter. During the month Jupiter will move westward among the stars much faster than Neptune so that at the end of the month the difference of right ascension between the two planets will be about nine degrees.

Occultations visible at Washington.

Date 1907	Star's Name	Magnitude.	IMMERSION. Washington M.T.	Angle from N pt.	EMERSION. Washington M.T.	Angle from N pt.	Duration.
			h m	°	h m	°	h m
Jan. 1	δ Cancri	4.1	10 16	116	11 30	256	1 14
8	ξ^1 Librae	5.7	19 45	85	20 54	326	1 09
9	Bradley 1987	6.5	15 09	71	15 54	333	0 45
16	50 Aquarii	5.9	5 32	117	6 13	192	0 41
17	ψ^2 Aquarii	4.6	5 00	91	6 05	212	1 05
24	*m* Tauri	5.0	12 40	103	13 48	249	1 08
25	BD.+19°, 1110	6.0	9 01	133	10 00	210	0 59
25	χ^1 Orionis	4.5	10 32	45	11 40	307	1 08
25	χ^4 Orionis	4.7	16 00	70	16 52	294	0 52
27	61 Geminorum	5.8	4 09	65	5 02	286	0 53
30	34 Leonis	6.4	9 54	111	11 12	282	1 18
31	Piazzi xi, 12	5.8	18 34	106	19 36	303	1 02

Phases of the Moon.

Central Standard Time.

		h	m
Last Quarter	1907 Jan.	6	20 47
New Moon		13	11 57
First Quarter		20	14 41
Full Moon		28	19 45

Phenomena of the Satellites of Jupiter.

1907 Central Standard Time, reckoning from noon.

Jan.	1	15h 58m	I Oc. Dis.	Jan.	4	9h 59m	I Tr. Eg.
	2	6 58	II Tr. In.			10 10	I Sh. Eg.
		7 15	II Sh. In.		5	4 50	I Oc. Dis.
		9 48	II Tr. Eg.			7 18	I Ec. Re.
		10 05	II Sh. Eg.		6	4 39	I Sh. Eg.
		13 16	I Tr. In.		7	4 59	III Sh. In.
		13 25	I Sh. In.			6 56	III Tr. Eg.
		15 33	I Tr. Eg.			8 02	III Sh. Eg.
		15 42	I Sh. Eg.			8 40	IV Oc. Dis.
	3	10 24	I Oc. Dis.			10 10	IV Oc. Re.
		12 49	I Ec. Re.			11 11	IV Ec. Dis.
		14 06	III Oc. Dis.			12 50	IV Ec. Re.
	4	5 03	II Ec. Re.			15 00	II Oc. Dis.
		7 42	I Tr. In.		9	9 13	II Tr. In.
		7 53	I Sh. In.			5 53	II Sh. In.

Phenomena of the Satellites of Jupiter.—(Continued.)

Jan.	9	12h 03m	II Tr. Eg.	Jan.	19	11h 8m	I Ec. Re.
		12 43	II Sh. Eg.		20	5 36	I Tr. In.
		15 00	I Tr. In.			6 11	I Sh. In.
		15 19	I Sh. In.			7 53	I Tr. Eg.
	10	12 08	I Oc. Dis.			8 28	II Sh. Eg.
		14 44	I Ec. Re.		21	5 37	I Ec. Re.
	11	7 38	II Ec. Re.			10 32	III Tr. In.
		9 26	I Tr. In.			12 57	III Sh. In.
		9 48	I Sh. In.			13 32	III Tr. Eg.
		11 43	I Tr. Eg.			16 02	III Sh. Eg.
		12 05	I Sh. Eg.		22	13 47	II Tr. In.
	12	6 34	I Oc. Dis.			15 06	II Sh. In.
		9 13	I Ec. Re.		24	5 10	IV Ec. Dis.
	13	6 09	I Tr. Eg.			7 07	IV Ec. Re.
		6 34	I Sh. Eg.			15 39	I Oc. Dis.
	14	7 12	III Tr. In.		25	5 48	III Ec. Re.
		8 58	III Sh. In.			8 38	II Oc. Dis.
		10 13	III Tr. Eg			12 48	II Ec. Re.
		12 02	III Sh. Eg.			12 55	I Tr. In.
	15	16 17	IV Tr. In.			13 37	I Sh. In.
		17 51	IV Tr. Eg.			15 12	I Tr. Eg.
	16	11 29	II Tr. In.			15 54	I Sh In.
		12 29	II Sh. In.		26	10 05	I Oc. Dis.
		14 19	II Tr. Eg.			13 03	I Ec. Re.
		15 20	II Sh. Eg.		27	5 47	II Tr. Eg.
	17	13 53	I Oc. Dis.			7 17	II Sh. Eg.
	18	6 22	II Oc. Dis.			7 22	I Tr. In.
		10 13	II Ec. Re.			8 06	I Sh. In.
		11 10	I Tr. In.			9 39	I Tr. Eg.
		11 42	I Sh. In.			10 23	I Sh. Eg.
		13 27	I Tr. Eg.		28	7 32	I Ec. Re.
		14 00	I Sh. Eg.			13 56	III Tr. In.
		8 20	I Oc. Dis.			16 56	III Tr. Eg.

Note.—In., denotes ingress; Eg., egress; Dis., disappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

COMET AND ASTEROID NOTES.

Ephemeris of Comet *e* 1906.

1906		α			δ		log *r*	log Δ	Br.
		h	m	s	°	′			
Dec.	1	23	0	12	+4	6.2	0.4001	0.3354	0.14
	3		2	21	4	10.6			
	5		4	32	4	15·4	0.4039	0.3495	0.13
	7		6	45	4	20.7			
	9		9	1	4	26.4	0.4077	0.3634	0.12
	11		11	19	4	32.6			
	13		13	38	4	39.2	0.4115	0.3768	0.11
	15		16	0	4	46.2			
	17		18	23	4	53.7	0.4152	0·4001	0.10
	19		20	48	5	1.5			
	21	23	23	14	+5	9.7	0.4189	0.4030	0.00

The New Comet *f* 1906 Thiele.—A telegram received from Harvard College Observatory, November 12, announced the discovery of comet by Holger Thiele, at Copenhagen, on November 10, and gave two positions of the comet on that date. The comet is easily seen in a small telescope and is quite a conspicuous object in a large instrument. It has no tail but is round, about 5′ in diameter, with a strong central condensation, so that measures of its position are comparatively good.

The discovery position is in Leo, at the left paw of the lion. The motion is quite rapid toward the northeast and by December the comet will have passed through Leo and Leo Minor into Ursa Major.

The following positions are at hand:

Greenwich M.T.	R.A. h m s	Decl. ° ′ ″	Observer	Place
Nov. 10.5088	9 15 21.3	+12 16 50	Thiele	Copenhagen
10.6758	9 16 03.3	+12 28 31	Thiele	Copenhagen
12.0200	9 21 52.0	+14 02 42	Fath	Lick Obs.
12.8485	9 25 32.9	+15 03 56	Wilson	Northfield
12.8624	9 25 36.1	+15 04 50	Morgan	Glasgow, Mo.
13.9757	9 30 40.4	+16 27 56	Fath	Lick Obs.
18.8532	9 54 44.8	+22 52 42	Wilson	Northfield

Preliminary elements have been computed by Messrs. Duncan and Williams of Bloomington, Indiana, and by H. R. Morgan of Glasgow, Mo., which agree fairly well, but they depend upon observations taken November 10, 11 and 12, and therefore too close together to give more than a rough approximation to the elements of the orbit.

Elements of Comet *f* 1906 by Messrs. Duncan and Williams.

$T = 1906$ Dec. 12.45 Gr. M. T.
$\omega = 31° \ 34'$
$\Omega = 86 \ \ 26$
$i = 69 \ \ 52$
$q = 1.153$

EPHEMERIS.

Gr. M. T.	R. A. h m s	Decl. ° ′	Brightness
Nov. 14.5	9 33 20	+17 10	1.22
18.5	9 54 57	+22 52	
22.5	10 21 17	+29 15	
26.5	10 53 48	+36 01	1.83

Elements of Comet *f* 1906 by H. R. Morgan.

$T = 1906$ Dec. 14.56 Gr. M. T.
$\omega = 33° \ 46'$
$\Omega = 86 \ \ 56$
$i = 71 \ \ 11$
$q = 1.148$

EPHEMERIS

Gr. M. T.	R. A. h m s	Decl. ° ′	Brightness
Nov. 16.5	9 43 15	+19 50	1.37
20.5	10 06 44	+25 50	
24.5	10 35 44	+32 27	
28.5	11 11 52	+39 16	2.11

Elements and Ephemeris of Comet (Thiele) *f* 1906.

Observations at Copenhagen Nov. 10, and Glasgow Nov. 12 and Nov. 14 gave the elements

$T = 1906$ Nov. 22.54256 Gr. M. T.
$\omega = 9° \ 58' \ 46''$
$\Omega = 85 \ \ 8 \ \ 46$ } 1906
$i = 57 \ \ 21 \ \ 20$
$q = 1.21567$

(O—C) Nov. 12: $\cos\beta\Delta\lambda = +12''$, $\Delta\beta = 0$
Nov. 17: $\cos\delta\Delta\alpha = -41''$, $\Delta\delta = -50''$
$T_3 - T_1 = 0^d.00029$

As Nov. 17 was not well represented, the following elements were computed from the observations; Copenhagen Nov. 10; Glasgow Nov. 14, and Nov. 17; and the ephemeris from them.

ELEMENTS:

$T = 1906$, Nov. 21.68549 Gr. M. T.
$\omega = 6° \ 6' \ 24''.8$
$\Omega = 85 \ \ 0 \ 57 \ .3$ } 1906.0
$i = 56 \ 47 \ 35 \ .2$
$q = 1.215200$

(O—C)
$\cos\beta\Delta\lambda = -4''.2$
$\Delta\beta = +1.9$
$T_3 - T_1 = 0^d.00082$

CONSTANTS TO THE EQUATOR.

$x = r\,[9.742306] \sin(180 \ \ 3 \ \ 33.0 + v)$
$y = r\,[9.981652] \sin(116 \ 40 \ \ 25.2 + v)$
$z = r\,[9.944875] \sin(\ 35 \ 51 \ \ 30.5 + v)$

EPHEMERIS.

1906 Gr. M. T.	α app. h m s	δ app. ° ′ ″	log Δ.	Light
Nov. 22.5	10 14 59	+27 56 43	9.8065	1.29
26.5	10 39 38	33 33 11	9.8005	
30.5	11 7 1	38 57 43	9.8014	
Dec. 4.5	11 37 4	43 54 49	9.8089	1.24
8.5	12 9 23	48 12 10	9.8223	
12.5	12 43 13	51 42 57	9.8402	
16.5	13 17 27	54 26 26	9.8614	0.91
20.5	13 50 54	+56 26 43	9.8845	

Morrison Observatory, Nov. 19. HERBERT R. MORGAN.

New Comet *g* 1906 (Metcalf).—A faint comet was discovered by Rev. J. H. Metcalf of Taunton, Mass., upon a photograph taken by him on the night of Nov. 14. It is in the constellation Eridanus and moving rather slowly southward. The comet is scarcely visible in a 5-inch telescope but in the 16-inch it is easily observed, having a strong central condensation. The following positions are at hand:

Gr. M. T.	R. A. h m s	Decl. ° ′ ″	Observer	Place
Nov. 14.6145	4 04 35	−2 15.8	Metcalf	Taunton
16.5917	4 04 16	−2 44.8	Metcalf	Taunton
16.6988	4 04 11.4	−2 46 55	Hammond	Washington
17.8141	4 03 55.7	−3 01 37	Fath	Lick Obs.
19.5965	4 03 30.7	−3 25 01	Wilson	Northfield

No elements have yet been received.

Numbering of Recently Discovered Asteroids.—In *A.N.* No. 4128 Mr. J. Bauschinger of the Royal Institute for Computing at Berlin assigns the following permanent numbers to asteroids which have been discovered during the year ending June 30, 1906 and for which there is sufficient observational data to determine their orbits

No.	Provisional Designation	Discoverer	Date of Discovery
570	1905 QX	Wolf	1905 July 30
571	QZ	Götz	Sept. 4
572	RB	Götz	Sept. 19
573	RC	Wolf	Sept. 19
574	RD	Wolf	Sept. 19
575	RE	Wolf	Sept. 19
576	RF	Götz	Sept. 22
577	RH	Wolf	Oct. 20
578	RZ	Wolf	Nov. 1
579	SD	Kopff	Nov. 3
580	SE	Wolf	Dec. 17
581	SH	Metcalf	Dec. 24
582	1906 SO	Kopff	1906 Jan. 23
583	1905 SP	Palisa	1905 Dec. 31
584	1906 SY	Kopff	1906 Jan. 15
585	TA	Kopff	Feb. 16
586	TC	Wolf	Feb. 21
587	TF	Wolf	Feb. 22
588	TG	Wolf	Feb. 22
589	TM	Kopff	March 3
590	TO	Wolf	March 4
591	TP	Kopff	March 14
592	TS	Wolf	March 18
593	TT	Kopff	March 20
594	TW	Wolf	March 27
595	TZ	Wolf	March 27
596	UA	Kopff	Feb. 21
597	UB	Wolf	April 16
598	UC	Wolf	April 13
599	UJ	Metcalf	April 25
600	UM	Metcalf	June 14
601	UN	Wolf	June 21

Of the others which were discovered during the year twelve were found to be identical with those having earlier numbers and fifty-four lacked sufficient observational data to determine their orbits.

The asteroid family is now increasing so fast that it is no wonder the observers cannot keep track of them. That 54 out of 98 discovered in a year should get away and be lost before the elements of their orbits could be determined is not surprising. Most of these were from the 12th to the 14th magnitude and it is a question whether it is worth the while to follow them up.

Naming of Asteroids.—In *A. N.* 4128 Dr. M. Wolf gives the following names to those discovered in the years 1900-1905:

No.	Designation	Discovered	Name
459	1900 FM	1900 Oct. 22	Signe
461	FP	" "	Saskia
464	1901 FV	1901 Jan. 9	Megaira
465	FW	13	Alekto
466	FX	17	Tisiphone
467	FY	9	Laura
468	FZ	13	Lina
471	GN	June 7	Papagena
473	GC	Feb. 13	Nolli
474	GD	13	Prudentia
490	1902 JP	1902 Sept. 3	Veritas
492	JR	" "	Gismonda
495	KG	Oct. 25	Eulalia
500	1903 LA	1903 Jan. 16	Selinur
501	LB	18	Urhixidur
502	LC	19	Sigune
513	LY	Aug. 24	Centesima
514	MB	"	Armida
515	ME	Sept. 20	Athalia
524	1904 NN	1904 Mar. 14	Fidelio
525	NO	"	Adelaide
527	NR	20	Euryanthe
528	NS	"	Rezia
529	NT	"	Preciosa
530	NV	April 11	Turandot
531	NW	12	Zerlina
539	OL	Aug. 2	Pamina
540	ON	3	Rosamunde
541	OO	4	Deborah
549	PK	Nov. 15	Jessonda
550	1904 PL	1904 Nov. 16	Senta
551	PM	"	Ortrud
552	PO	Dec. 14	Sigelinde
553	PP	27	Kundry
555	1905 PT	1905 Jan. 14	Norma
557	PY	26	Violetta
558	QB	Feb. 9	Carmen
559	QD	Mar. 8	Nanon
560	QF	13	Delila
561	QG	26	Ingwelde
562	QH	Apr. 3	Salome

VARIABLE STARS.

New Variable of the Algol Type 121.1906 Draconis.—In *A. N.* 4128 Professor W. Ceraski announces a new variable of the Algol type, discovered by Mme. L. Ceraski on the Moscow photographs. Its position is

1855.0	$\alpha = 19^h$	00^m	25^s		$\delta = +58°$	31′.3
1900.0	$= 19$	1	08		$= +58$	35 .2

It is ordinarily of magnitude 9.3 but at a minimum observed October 18, 1906, at 12^h Moscow mean time it sank to 9.8. The period is unknown.

Variable RZ Ophiuchi. In *A.N.* 4128 Mr. F. C. Jordan states that he obtained photographs of the vicinity of this variable on the nights of August 14, 15, 16, 18, 20, 22, 25, and 27 and that these photographs show no change in the light of the star. M. Blajko of Moscow had predicted a minimum between August 15 and August 25.

Photographic and Visual Ranges of Variation.—In *A. N.* 4125 Mr. Alexander Wilkins of the Kuffner Observatory at Vienna, gives light curves of the variable SU and X Cygni, T and U Vulpeculae and S Sagittae. He finds that all of these stars are fainter photographically than visually and the range of their variation is considerably greater according to the photographs than according to visual observations. This is plainly shown in the following table:

	Limiting Values of Magnitude		
	Photographic	Visual	Ratio of Photographic to Visual range
SU Cygni	7.1 — 8.3	6.6 — 7.4	1.5
X Cygni	7.3 — 9.0	6.2 — 7.3	1.9
T Vulpeculae	6.3 — 7.5	5.4 — 6.2	1.5
S Sagittae	6.4 — 7.7	5.7 — 6.4	1.9
U Vulpeculae	8.4 — 9.5	6.9 — 7.6	1.6

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei			Algol			R T Persei			λ Tauri			RW Geminorum		
	d	h		d	h		d	h		d	h		d	h
Jan.	1	15	Jan.	3	3	Jan.	13	20	Jan.	17	8	Jan.	13	4
	4	3		6	0		14	16		21	7		16	1
	6	15		8	21		15	13		25	6		18	21
	9	3		11	19		16	9		29	5		21	18
	11	15		14	15		17	5	RW Tauri				24	15
	14	3		17	12		18	2	Jan.	5	3		27	12
	16	14		20	8		18	22		7	22		30	8
	19	2		23	5		19	18		10	16	R Canis Maj.		
	21	14		26	2		20	15		13	11	Jan.	0	14
	24	2		28	23		21	11		16	5		1	17
	26	14		31	20		22	8		19	0		2	21
	29	2	RT Persei				23	4		24	12		4	0
	31	13	Jan.	1	2		24	0		27	7		5	3
				2	19		24	21		30	1		6	6
Z Persei				3	15		25	17	RW Persei				7	10
				4	12		26	14					8	13
Jan.	1	18		5	8		27	10	Jan.	0	5		9	16
	4	19		6	4		28	6		13	10		10	19
	7	20		7	1		29	3		26	15		11	22
	10	22		7	21		29	23	RS Cephei				13	2
	13	23		8	17		30	20	Jan.	0	5		14	5
	17	1		9	14	λ Tauri				12	15		15	8
	20	2		10	10	Jan.	1	13		25	1		16	12
	23	3		11	7		5	12	RW Geminorum				17	15
	26	4		12	3		9	11	Jan.	4	13		18	18
	29	6		12	23		13	10		7	10		19	22
										10	7			

Minima of Variabe Stars of the Algol Type.—Continued.

R Canis Maj.

	d	h
Jan.	21	1
	22	4
	23	7
	24	11
	25	14
	26	17
	27	20
	29	0
	30	3
	31	6

Y Camelopardis

Jan.	3	3
	6	10
	9	18
	13	1
	16	8
	19	16
	22	23
	26	6
	29	13

RR Puppis

Jan.	4	22
	11	8
	17	19
	24	5
	30	15

V Puppis

Jan.	2	4
	3	15
	5	2
	6	13
	8	0
	9	11
	10	22
	12	9
	13	20
	15	6
	16	18
	18	5
	19	15
	21	2
	22	13
	24	0
	25	11
	26	22
	28	9
	29	20
	31	6

X Carinæ
Period 13^h

Jan.	1	5
	2	7
	3	9
	4	11
	5	13
	6	15
	7	17
	8	19
	9	21

X Carinæ
Period 13^h

	d	h
Jan.	10	23
	12	1
	13	3
	14	5
	15	7
	16	9
	17	11
	18	13
	19	15
	20	17
	21	19
	22	21
	23	23
	25	1
	26	3
	27	5
	28	7
	29	9
	30	11
	31	13

S Cancri

Jan.	3	16
	13	4
	22	15

S Velorum

Jan.	2	13
	8	11
	14	9
	20	8
	26	6

RR Velorum

Jan.	2	17
	4	14
	6	10
	8	7
	10	3
	12	0
	13	20
	15	17
	17	13
	19	10
	21	6
	23	3
	24	23
	26	20
	28	16
	30	13

SS Carinae

Jan.	3	2
	7	6
	10	23
	13	20
	17	3
	20	11
	23	18
	27	1
	30	8

Z Draconis

Jan.	2	7
	3	15
	5	0
	6	8
	7	17
	9	2
	10	10
	11	19
	13	3
	14	12
	15	20
	17	5
	18	14
	19	22
	21	7
	22	15
	24	0
	25	9
	26	17
	28	2
	29	11
	30	19

δ Libræ

Jan.	2	14
	4	22
	7	5
	9	13
	11	21
	14	5
	16	13
	18	21
	21	5
	23	12
	25	20
	28	4
	30	12

U Coronae

Jan.	3	22
	7	9
	10	20
	14	7
	17	18
	21	5
	24	16
	28	2
	31	13

R Arae

Jan.	2	14
	7	0
	11	11
	15	21
	20	7
	24	17
	29	3

U Ophiuchi

Jan.	1	5
	2	1
	2	21
	3	17
	4	13

U Ophiuchi

Jan.	5	10
	6	6
	7	2
	7	22
	8	18
	9	14
	10	10
	11	6
	12	3
	12	23
	13	19
	14	15
	15	11
	16	7
	17	3
	18	0
	18	20
	19	16
	20	12
	21	8
	22	4
	23	0
	23	21
	24	17
	25	13
	26	9
	27	5
	28	1
	28	21
	29	17
	30	14
	30	10

Z Herculis

Jan.	2	5
	4	2
	6	5
	8	2
	10	5
	12	2
	14	4
	16	1
	18	4
	20	1
	22	4
	24	1
	26	4
	28	1
	30	4

RS Sagittarii

Jan.	0	11
	2	21
	5	7
	7	17
	10	3
	12	13
	14	23
	17	9
	19	19
	22	5
	24	15

RS Sagittarii

Jan.	27	1
	29	11
	31	21

V Serpentis

Jan.	3	14
	7	2
	10	12
	13	23
	17	10
	20	21
	24	8
	27	19
	31	6

RR Draconis

Jan.	2	18
	5	14
	8	10
	11	6
	14	2
	16	22
	19	18
	22	13
	25	9
	28	5
	31	1

RZ Cassiopeiae

Jan.	1	17
	2	21
	4	2
	5	7
	6	11
	7	16
	8	21
	10	1
	11	6
	12	11
	13	16
	14	20
	16	1
	17	6
	18	10
	19	15
	20	20
	22	0
	23	5
	24	10
	25	14
	26	19
	28	0
	29	4
	30	9
	31	14

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

RW Cassiop.

	d	h
	(−5	19)
Jan.	4	12
	19	7

RX Aurigae

	(−4	0)
Jan.	7	13
	19	13
	31	14

Y Aurigæ

	(−0	18)
Jan.	1	20
	5	16
	9	13
	13	10
	17	6
	21	3
	24	23
	28	20

T Monocerotis

	(−7	23)
Jan.	26	5

W Geminorum

	(−2	22)
Jan.	4	14
	12	12
	20	10
	28	8

ζ Geminorum

	(−5	0)
Jan.	9	20
	19	23
	30	3

V Carinæ

	(−2	4)
Jan.	1	15
	8	7
	15	0
	21	17
	28	9

T Velorum

	(−1	10)
Jan.	2	23
	7	15
	12	6
	16	22
	21	13

T Velorum

	(−1	10)
Jan.	26	4
	30	20

W Carinæ

	(−1	0)
Jan.	2	15
	7	0
	11	9
	15	17
	20	2
	24	11
	28	20

W Urs. Maj.

Minimum
Period 4^h
Jan. 1-31 21^h

S Muscæ

	(−3	11)
Jan.	2	15
	12	7
	21	23
	31	14

T Crucis

	(−2	2)
Jan.	3	20
	10	13
	17	7
	24	0
	30	18

R Crucis

	(−1	10)
Jan.	2	16
	8	12
	14	8
	20	4
	25	23
	31	19

S Crucis

	(−1	12)
Jan.	2	5
	6	22
	11	14
	16	6
	20	23
	25	16
	30	9

W Virginis

	(−8	5)
Jan.	2	16

W Virginus

	(−8	5)
Jan.	19	23

V Centauri

	(− 1	11)
Jan.	4	5
	9	17
	15	5
	20	16
	26	4
	31	16

R Triang. Austr.

	(− 1	0)
Jan.	1	7
	4	17
	8	2
	11	11
	14	21
	18	6
	21	15

R Triang. Austr.

	(− 1	0)
	25	1
	28	10
	3	19

S Triang. Austr.

	(−2	2)
Jan.	1	23
	8	6
	14	14
	20	22
	27	6

S Normæ

	(− 4	10)
Jan.	8	14
	18	9
	28	3

RV Scorpii

	(−1	10)
Jan.	2	5
	8	7
	14	8
	20	10
	26	11

RV Ophiuchi

Minimum

Jan.	2	4
	5	20
	9	13
	13	5

RV Ophiuchi

Minimum

Jan.	16	22
	20	14
	24	7
	27	23
	31	16

X Sagittae

	(−2	22)
Jan.	3	6
	10	6
	17	6
	24	7
	31	7

Y Ophiuch

	(−6	5)
Jan.	3	21
	21	0

W Sagittarii

	(−3	0)
Jan.	6	23
	14	14
	22	4
	29	18

Y Sagittarii

	(−2	2)
Jan.	6	9
	12	3
	17	22
	23	17
	29	11

U Sagittarii

	(−2	23)
Jan.	3	2
	9	20
	16	13
	23	7
	30	1

δ Lyrae

	(−3	2)
	(−3	7)
Jan.	0	15
	7	2
	13	13
	20	0
	26	11

VY Cygni

	(−2	2)
Jan.	9	9
	14	9

VY Cygni

	(−2	2)
Jan.	19	2
	19	22
	21	19
	23	16
	25	13
	27	10
	29	7
	31	4
	24	2
	28	19

δ Cephei

	(−1	10)
Jan.	1	17
	7	1
	12	10
	17	19
	23	4
	28	12

V Lacertae

	(− 1	17)
Jan.	2	17
	7	17
	12	16
	17	16
	22	16
	27	15

88.1906 Lacert.

Minimum

Jan.	5	11
	10	21
	16	8
	21	18
	27	5

U Pegasi

Period 4^h 30^m
every 10th max.

Jan.	1	4
	3	1
	4	22
	6	19
	8	16
	10	13
	12	10
	14	7
	16	4
	18	1
	19	22
	21	19
	23	16
	25	13
	27	10
	29	7
	31	4

Approximate Magnitudes of Variable Stars on Nov. 1, 1906.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900.		Decl. 1900.		Magn.	Name.	R. A. 1900.		Decl. 1900.		Magn.
	h	m	°	′			h	m	°	′	
X Androm	0	10.8	+46	27	10.5*d*	R Cancri	8	11.0	+12	2	6 5
T Androm		17.2	+26	26	13.0*d*	V Cancri		16.0	+17	36	12 *d*
T Cassiop.		17.8	+55	14	10.5*d*	U Cancri		30.0	+19	14	12 *d*
R Androm.		18.8	+38	1	12.5*d*	S Hydrae		48.4	+ 3	27	8.0 *i*
S Ceti		19.0	— 9	53	13.5	Y Draconis	9	31.1	+78	18	9.5*d*
Y Cephei		31.3	+79	48	10	R Leo. Min.		39.6	+34	58	8.5 *i*
U Cassiop.		40.8	+47	43	9 8*d*	R Leonis		42.2	+11	54	10.0
V Androm.		44.6	+35	6	9	R Urs. Maj.	10	37.6	+69	18	10.5 *i*
RR Androm.		45.9	+33	50	8.5*d*	R Comae	11	59.1	+19	20	11.5*d*
W Cassiop.		49.0	+58	1	9.6*d*	T Urs. Maj.	12	31.8	+60	2	10.5*d*
U Androm.	1	9.8	+40	11	<14	RS Urs. Maj.		34.4	+59	3	9.0 *d*
S Piscium		12.4	+48	24	<14	S Urs. Maj.		39.6	+61	38	8.0
U Piscium		17.7	+12	21	<14	T Urs. Min.	13	32.6	+73	56	13.5
S Cassiop.		17.3	+72	5	8.2*d*	R Can. Ven.		44.6	+40	2	12
RU Androm.		32.8	+38	10	<13.5	S Bootis	14	19.5	+54	16	9.0 *i*
Y Androm.		33.7	+38	50	9.0*d*	V Bootis		25.7	+39	18	9.5*d*
X Cassiop.		49.8	+58	46	12	R Camelop.		25.1	+84	17	8.5*d*
U Persei		52.9	+54	20	9.5	R Bootis		32.8	+27	10	7.0
S Arietis		59.3	+12	3	12.8*d*	S Serpentis	15	17.0	+14	40	11.5*d*
R Arietis	2	10.4	+24	35	13.5	S Coronae		17.3	+31	44	12.7
W Androm.		11.2	+43	50	14	S Urs. Min.		33.4	+78	58	9.5*d*
Z Cephei		12.8	+81	13	12.5 *i*	— Coronae		45.3	+37	49	9.0*d*
o Ceti		14.3	— 3	26	4.5 *i*	R Serpentis		46.1	+15	26	10.5*d*
S Persei		15.7	+58	8	9.0 *i*	V Coronæ		46.0	+39	52	12.0
R Ceti		20.9	— 0	38	13.5	R Herculis	16	1.7	+18	38	12.0*d*
RR Cephei		29.4	+80	42	11	RR Herculis		1.5	+50	46	9.2*d*
R Trianguli		31.0	+33	50	6.3*d*	W Coronae		11.8	+38	3	8.0
T Arietis		42.8	+17	6	9.5	V Ophiuchi		21.2	−12	12	10.5*d*
W Persei		43.2	+56	34	9.0	U Herculis		21.4	+19	7	11.5*d*
R Persei	3	23 7	+35	20	<13	W Herculis		31.7	+37	32	13.8
Nov. Per. No. 2		24.4	+43	34	13.0*d*	R Draconis		32.4	+66	58	12.5
R Tauri	4	22.8	+ 9	56	9.0 *i*	S Herculis		47.4	+15	7	12.5
T Camelop.		30.4	+65	57	13.5	RT Herculis	17	6.8	+27	11	13.5*d*
X Camelop.		32.6	+74	56	9.5 *i*	Z Ophiuchi		14.5	+ 1	37	8.0
V Tauri		46.2	+17	22	10.5*d*	RS Herculis		17.5	+28	1	8.0 *i*
R Orionis		53.6	+ 7	59	9.5 *i*	T Draconis		54.8	+58	14	10.0
R Aurigae	5	9.2	+53	28	8.5*d*	RY Herculis		55.4	+19	29	8.5 *i*
S Aurigae		20.5	+34	4	10	V Draconis		56 3	+54	53	12 *d*
S Orionis		24.1	— 4	46	10 *d*	RW Herculis	18	1.7	+22	4	13.5
T Orionis		30.9	— 5	32	10.5	T Herculis		5.3	+31	0	13.5*d*
S Camelop.		30.2	+68	45	8.5 *i*	W Draconis		5.4	+65	56	9.0 *i*
U Aurigae		35.6	+31	59	10 *d*	X Draconis		6.8	+66	8	<13.5
U Orionis		49.9	+20	10	11 *d*	W Lyrae		11.5	+36	38	11.0 *i*
V Camelop.		49.4	+74	30	<13.5	RZ Herculis		32.7	+25	58	10.0 *i*
X Aurigae	6	4.4	+50	14	13	X Ophiuchi		33.6	+ 8	44	9.0*d*
V Aurigae		16.5	+47	45	10.0 *i*	RY Lyrae		41.2	+34	34	<14
X Gemin.		40.7	+30	23	10 *i*	RW Lyrae		42.2	+43	32	<14
R Lyncis		53.0	+55	28	7.5 *i*	RX Lyrae		50.4	+32	42	12
V Can Min.	7	1.5	+ 9	1	10 *d*	ST Sagitt.		55 9	−12	54	9.5*i*
R Gemin.		1.3	+22	52	8.5*d*	Nova Aquil No. 2		54.4	— 4	39	<14
RR Monoc.		12.4	+ 1	17	11.5*d*	Z Lyrae		56 0	+34	49	13.5
V Gemin.		17.6	+13	17	12.5*d*	RT Lyrae		57.8	+37	22	10.5
S Can. Min.		27.3	+ 8	32	8.0 *i*	R Aquilae	19	1.6	+ 8	5	9.5 *i*
U Can. Min.		35.9	+ 8	37	9.0	V Lyrae		5.2	+29	30	11.0 *i*
S Gemin.		37.0	+23	41	8.5 *i*	RW Sagittarii		8.1	−19	2	11.5*d*
T Gemin.		43.3	+23	59	<12	RX Sagittarii		8.7	−18	59	12

Approximate Magnitudes of Variable Stars on Nov. 1, 1906.

(Continued.)

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn.
S Lyrae	19	9.1	+25	50	11.0*d*	X Delphini	20	50.3	+17	16	11.0 *i*
RS Lyrae		9.3	+33	15	<13	UX Cygni		50.9	+30	2	14.0
RU Lyrae		9.1	+41	8	12 *d*	R Vulpeculae		59.9	+23	26	13
U Draconis		9.9	+67	7	11 *d*	V Capric.	21	1.8	−24	19	9.0 *i*
W Aquilae		10.0	— 7	13	11 *i*	X Cephei		3.6	+82	40	13.5
T Sagittarii		10.5	−17	9	12.0	RS Aquarii		5.8	— 4	27	12.2*d*
R Sagittarii		10.8	−19	29	9.5 *i*	Z Capric.		5.0	−16	35	11.5*d*
RY Sagittarii		10.0	−33	42	7.5	R Equulei		8.4	+12	23	13.5
S Sagittarii		13.6	−19	12	14	T Cephei		8.2	+68	5	9.8*d*
Z Sagittarii		13.8	−21	7	14	RR Aquarii		9.8	— 3	19	11.0*d*
TZ Cygni		13.4	+50	0	10.5	X Pegasi		16.3	+14	2	13.5*d*
U Lyrae		16.6	+37	42	8.0 *i*	T Capric.		16.5	−15	35	10.0 *i*
T Sagittae		17.2	+17	28	8.8	S Cephei		36.5	+78	10	8.3 *i*
TY Cygni		29.8	+28	6	10	RU Cygni		37.3	+53	52	7.5 *i*
RT Aquilae		33.3	+11	29	11.5*d*	SS Cygni		38.8	+43	8	9.5*d*
R Cygni		34.1	+49	58	13.5*d*	RR Pegasi		40.0	+24	33	<12
RV Aquilae		35.9	+ 9	42	11.0*d*	V Pegasi		56.0	+ 5	38	12.5 *i*
RT Cygni		40.8	+48	32	8.5 *i*	U Aquarii		57.9	−17	6	<13
TU Cygni		43.3	+48	49	9.0	RT Pegasi		59.8	+34	38	<13.5
X Aquilae		46.5	+ 4	12	10.0 *i*	T Pegasi	22	4.0	+12	3	9.8 *i*
χ Cygni		46.7	+32	40	13.5	Y Pegasi		6.8	+13	52	<13.5
RS Aquilae		53.7	— 8	10	11.2*d*	RS Pegasi		7.4	+14	4	13.0*d*
Z Cygni		58.6	+49	46	10.0*d*	X Aquarii		13.2	−21	24	8.3
S Cygni	20	3.4	+57	42	<14	RT Aquarii		17.7	−22	34	8.0
RU Aquilae		8.0	+12	42	10	T Lacertae		17.9	+33	52	9.5
Z Aquilae		9.8	— 6	27	10	S Lacertae		24.6	+39	48	13.5
RS Cygni		9.8	+38	28	8.0 *i*	R Lacertae		38.8	+41	51	10.5 *i*
R Delphini		10.1	+ 8	47	8.5 *i*	S Aquarii		51.8	−20	53	9.5*d*
U Cygni		16.5	+47	35	7.8	RW Pegasi		59.2	+14	46	8.0 *i*
SX Cygni		11.6	+30	46	13 *d*	R Pegasi	23	1.6	+10	0	8.5*d*
RU Capric.		26.7	−22	2	13.2	V Cassiop.		7.4	+59	8	13 *d*
ST Cygni		29.9	+54	38	11.5*d*	W Pegasi		14.8	+25	44	9.5 *i*
Y Delphini		36.8	+11	30	9.0 *i*	S Pegasi		15.5	+ 8	22	9.5*d*
S Delphini		38.5	+16	44	12.8	R Aquarii		38.6	−15	50	10.7*d*
V Cygni		38.1	+47	47	11.8*d*	Z Cassiop		39.7	+56	2	13.5
Y Aquarii		39.2	— 5	12	10.0 *i*	Z Aquarii		47.1	−16	25	9.5*d*
T Delphini		40.7	+16	2	<13	RR Cassiop.		50.6	+53	10	11.0 *i*
V Aquarii		41.8	+ 2	4	8.5*d*	V Ceti		52.8	— 9	31	10.0*d*
W Aquarii		41.2	— 4	27	11.5*d*	R Cassiop.		53.3	+50	50	10.0*d*
U Capric.		42.6	−15	9	14	Z Pegasi		55.0	+25	21	12.5*d*
V Delphini		43.2	+18	58	<14	W Ceti		57.0	−15	14	7.5*d*
T Aquarii		44.7	— 5	31	8.0 *i*	Y Cassiop.		58.2	+55	7	14
RZ Cygni		48.5	+46	59	12.0 *i*						

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Vassar College, Whiteside, and Harvard Observatories.

Nomenclature of Recently Discovered Variable Stars.

Provis. Notation A. N.	Name	Position for 1900.0 R. A. h	m	s	Decl. °	′	Prec. 1900 R. A. s	Decl. ′
32.1906	RV Cephei	0	7	45	+73	18.0	+3.22	+0.33
31.1906	RU Cephei	1	8	8	84	36.3	7.22	0.32
77.1906	RZ Cassiopeiae	2	39	54	+69	12.8	+5.34	0.26

Nomenclature of Recently Discovered Variable Stars—Continued.

Provis. Notation A. N.	Name	Chart Place R. A. h m s	Decl. ° ′	Magnitude Max. m	Min. m	
6.1904	RX Cassiopeiae	2 58 49	+67 11.4	+5.31	+0.24	
35.1906	RX Persei	3 44 51	32 43.2	3.79	0 19	
29.1906	RW Persei	4 13 20	42 4.3	4.15	0.15	
279.1904	RX Tauri	4 32.8	8 9	3.25	0.12	
33.1906	RX Aurigae	4 54 28	39 48.7	4 14	0.09	
27.1906	RW Aurigae	5 1 20	30 16.4	3.83	0 08	
30.1906	RW Geminorum	5 55 24	23 8.2	3.64	+0.01	
34.1906	RT Camelopardalis	6 25 31	64 8.8	5.81	−0.04	
21.1904	RV Aurigae	6 27 36	42 34.8	4.29	0.04	
1.1906	T Lyncis	8 16 22	+33 50.3	3.81	0.19	
23.1904	RS Velorum	9 20 20	−48 26.4	2.11	0.26	
73.1906	SS Carinae	10 54 11	61 22.9	2.38	0.32	
26.1904	V Crucis	12 50.7	−57 21	3.53	0.33	
44.1906	X Coronae	15 45.2	+36 35	2.25	−0 19	
78.1906	SX Sagittarii	18 39 40	−30 35.8	3.85	+0.06	
46.1906	W Sagittae	19 15 4	+17 1 2	2.68	0.11	
76.1905	XZ Cygni	19 30 25	56 10.4	1.23	0.13	
68.1903	SV Aquilae	19 34 20	11 43.1	2.82	0.13	
72.1905	XY Cygni	19 45 13	41 24	2.02	0.15	
79.1903	SW Aquilae	19 46 0	12 34.0	2.81	0.15	
80.1903	SX Aquilae	19 46 15	12 58 0	2.80	0.15	
14.1904	XX Cygni	20 1 18	58 40.3	1.18	0.17	
48.1906	SY Aquilae	20 2 24	12 39.8	2.81	0.17	
79.1906	RR Delphini	20 38 52	13 55.1	2.82	0.21	
108.1905	RV Capricorni	20 55 55	−15 37.1	3.34	0.23	
94.1901	YY Cygni	21 18 39	+41 58.1	2.29	0.25	
166.1904	RZ Andromedae	23 5 3	42 30.8	2.66	0.32	
167.1904	SS Andromedae	23 7 1	52 21.1	2.67	0.32	
28.1906	RY Cassiopeiae	23 47 10	+58 11.2	+2.95	+0.33	
32.1906	RV Cephei	0 5 21	+73 3.0	10 9	13	ph
31.1906	RU Cephei	1 2 54	84 21.8	9.3	10.5	ph
77.1906	RZ Cassiopeiae	2 35 56	69 1.2	6.4	7.8	v
6.1904	RX Cassiopeiae	2 54 51	67 0.6	8.6	9.1	v
35.1906	RX Persei	3 42 1	32 34.8	10 8	<12.5	ph
29.1906	RW Persei	4 10 14	41 57.4	8.8	11.0	v
279.1904	RX Tauri	4 30.4	8 4	9	<12	ph
33.1906	RX Aurigae	4 51 22	39 44.4	7.2	8.1	v
27.1906	RW Aurigae	4 58 28	30 12 5	10 0	12.2	ph
30.1906	RW Geminorum	5 52 40	23 7.9	9.6	11.0	v
34.1906	RT Camelopardalis	6 21 9	64 10.3	9.5	<12 5	ph
21.1904	RV Aurigae	6 24 23	42 36.5	8.8	10	ph
1.1906	T Lyncis	8 13 31	+33 58.6	9.5	11	v
23.1904	RS Velorum	9 19 27	−48 20.0	?	?	ph
73.1906	SS Carinae	10 53 12	61 14.9	12.2	12.8	ph
26.1904	V Crucis	12 49.2	−57 13	?	?	ph
44.1906	X Coronae	15 43.5	+36 43	8.3	11.5	ph
78.1906	SX Sagittarii	18 38 4	−30 37.2	8.6	9.4	ph
46.1906	W Sagittae	19 13 3	+16 56.4	8.7	<11.5	ph
76.1905	XZ Cygni	19 29 30	56 4.6	8.7	9.3	v
68.1903	SV Aquilae	19 32 13	11 37.1	11	14	ph
72.1905	XY Cygni	19 43.7	41 17	10	<15	ph
79.1903	SW Aquilae	19 43 54	12 27.3	11.5	14	ph
80.1903	SX Aquilae	19 44 9	12 51.3	11	14.5	ph
14.1904	XX Cygni	20 0 25	58 32.7	10.5	11.5	v
48.1906	SY Aquilae	20 0 17	12 32.2	9.5	<11	ph
79.1906	RR Delphini	20 36 45	+13 25.5	9.5	<10.5	v
108.1905	RV Capricorni	20 53 25	−15 47.5	9.2	10.1	ph
94.1901	YY Cygni	21 16 56	+41 46.7	8.8	9.5	v
166.1904	RZ Andromedae	23 3 4	52 16.2	8.8	9.5	v
167.1904	SS Andromedae	23 5 0	52 6.4	8.9	9.6	v
28.1906	RY Cassiopeiae	23 45 0	+57 56.2	9.2	10.1(?)	v

GENERAL NOTES.

Latitude and Longitude of the Solar Observatory. The latitude and longitude of the Solar Observatory, on Mount Wilson, California, as recently determined is

Latitude	34°	12′	59″.53
Longitude	118°	3	34 .89

This point locates the place of the Snow telescope of the Solar Observatory. These coördinates have been determined with great care.

The Precision of Hipparchus. In these days of accurate work in practical Astronomy, it is interesting to remember what Hipparchus (about 120 B. C.) could do and did do without the aid of fine astronomical instruments of any kind, especially those of the modern type.

By observing the star η Canis he said the precession of the Equinoxes must be 59″. Its true value is 50″.2. He measured the length of the year within nine minutes of its true value; he determined the inclination of the ecliptic to the celestial equator to be 23° 51′. It then was 23° 46′. He made the lunar parallax 57′, which is about its average value. He made the eccentricity of the apparent solar orbit around the Earth as one twenty-fourth, its true value being about one-thirtieth; he found the perigee and mean motion of the Sun and Moon, and calculated the shifting of the plane of the Moon's motion. He worked out the synodic periods of the five planets then known. He did all this with very little instrumental aid compared with what the modern astronomer enjoys in this regard, and his work was good enough to give him the merited name of "Father of Astronomy" by some of the wise ones of later times, although he used the method of epicycles to explain the motions of the planets and that of the Sun and the Moon.

His attention to observation and the uses to be made of it indicate the natural bent of his mind, as one remarkably strong in science. He sees a new star in the heavens, he at once concludes that the stars ought to be charted for useful knowledge in these ways, and the result is, that he makes the first star catalogue which we have, containing 1080 stars. Another characteristic thing about him was the fact that there was not mathematics enough, in kind, to do the work he needed to do, so he invented a trigonometry, and thus gave to the science a new branch of very great value. Hipparchus's record was certainly a noble one.

Origin of Standard Time. In an address made at the first reunion of the descendants of Henry Doude, held at the Hammonassett House, Madison, Conn., Sept. 2, 1885, Professor Charles F. Dowd, Saratoga, N. Y., made the following statement in the course of his address:

"In relation to 'Standard Time', with which you were pleased to connect my name in calling me, I do not think it would become me to say much here. I may say, perhaps, it is so simple that everybody knows all about it, and can use it, without any reference to me, as its author, and so practical that it is adopted upon the North American Continent from the Atlantic to the Pacific Perhaps it would not add to my reputation, in your estimation, to know that it took me three years, from 1869 to 1872, to bring out this simple thing from the compli-

cations in which it was involved, and eleven more, or till 1883, to make all believe it was simple and practical enough to be adopted."

For some things in the history of the standard time movement in the United States, See Vol. I *Sidereal Messenger* p. 180, also S. M. Vol. II. p. 278. The history of its adoption in Minnesota has not yet been written. It should be.

Sir David Gill, Astronomer Royal at Capetown, South Africa closes his astronomical work there. From a recent paper from Capetown the following is taken:

"A farewell dinner to Sir David Gill, who leaves South Africa at the beginning of next month after twenty-seven years' service as Astronomer Royal, will be given in the City Club on Thursday, September 27, at eight o'clock. In the absence of Dr. Jameson, who before he left for England expressed his great regret at his inability to be present on the occasion, the Hon. Dr. Smartt will preside. Among those who have already intimated their cordial support of the movement are the Right Hon. Sir Henry de Villiers, His Grace the Archbishop, Sir John Buchanan, Dr. Thomas Muir, the Hon. Mr. J. X. Merriam, M. L. A., Mr. J. W. Jagger, M. L. A., Mr. John Garlick, M. L. A., Hon. Edmund Powell, M. L. C., Sir Abercrombie Smith, Mr. Malan, M. L. A., Sir Edmund Stevenson, Rev. J. M. Russell, Mr. Hector Mackenzie, Dr. J. C. Beattie, Mr. L. Péringuey, and many others. Applications for tickets (price 25s.) may be made to the secretary, David Gill Dinner Committee, P. O. Box 11, Cape Town."

An International Southern Telescope is the title of a paper read last April before the American Philosophical Society at the Franklin bi-centennial meeting, by Professor Edward C. Pickering.

The summary of this valuable paper we quote in full—"It may be said that the desire to have the largest telescope in the world and to carry our knowledge of the stars farther than has ever been done before, has been very widespread. It would be unwise to construct a refracting telescope much larger than those already made. A million and a half dollars would be required to duplicate one of our present observatories of the first class. A reflecting telescope of seven feet aperture, larger and more powerful than any hitherto constructed, could be made at a moderate price. It should be mounted in the best possible location as regards climate, and preferably in the southern hemisphere, to permit the study of neglected regions. Such an instrument would produce, by photography, results in quality much better than can be obtained elsewhere and in such quantity that no single institution could discuss and publish them. These photographs should be distributed throughout the world, and astronomers of all countries would thus be furnished with better material for study than they could possibly obtain themselves. They would also be offered every aid in discussing and publishing their conclusions.

The estimated cost of carrying out this plan is not more than half a million dollars, or one third of that of an observatory of the usual form as now constructed. Not only would results be obtained superior to those now secured anywhere else, but the work would be planned, not by a single astronomer, but by an international committee of astronomers, and the results would be discussed by the most distinguished specialist in each department. In this way, following the example of the great industrial enterprises of the country, the plan of work would be improved continually in every detail.

It will be difficult during the twentieth century to make as great an advance in science as was done during the life of Franklin in the eighteenth century or after his death in the nineteenth century. How could the name of Franklin be more highly honored than by initiating this undertaking at his bi-centennial? Were he living, is there any way that would be more in accordance with his wishes and aims in life than to advance a science, not only in a direction, but by a method, which would bring together, as here proposed, experts from all parts of the world in a single field of work?

It is not easy for a man who by life-long work and skill has accumulated a large fortune to expend it wisely in science and to his own satisfaction. It is hard for him to see it wasted or yielding inadequate results. Money thus given should be expended, as it has been acquired, by careful management and the use of strict business methods, in order to obtain the greatest return for every disbursement.

The name of a donor could in no way be better immortalized than by associating it with such a real advance in the greatest problem to the solution of which the mind of man has aspired,—the study of the sidereal universe.

Re-Observation of Jupiter's Seventh Satellite. The first observation of the seventh satellite of Jupiter at the present opposition was secured by the Crossley reflector at Lick Observatory September 17. The image of the satellite (with one hour's exposure) was extremely faint. The identity of the object was only made certain from plates secured on September 25 and 26, with longer exposures.

The position of the satellite with respect to its primary September 25, $23^h\ 30^m$ p. s. t. was

Position angle	119° 4′
Distance	42′.96

A comparison of this place with Ross's ephemeris published in *A. N.* 4101 gives the following residuals—in the sense observed minus ephemeris:—

Position angle	−1°.1
Distance	0′.2

Mr. C. D. Perrine of Lick Observatory gives the above information in *Publications of the Astronomical Society of the Pacific* No. 110. The agreement of the observed position of the new satellite with the predicted position in the ephemeris is very close. This object is an exceedingly faint one, and work upon it for definite results must not be very difficult.

Re-Observation of Jupiter's Sixth Satellite. This new satellite of Jupiter is not so faint as the seventh, and Mr. Perrine of Lick Observatory secured on August 26, $15^h\ 10^m\ 30^s$ the following position, in p. s. t:—

Right Ascension	$6^h\ 21^m\ 24^s.99$
Decl.	22° 38′ 32″.0

The position of the satellite with reference to Jupiter is:

Position angle	210° 14′
Distance	29′.0

Re-Observation of Phoebe, Saturn's Ninth Satellite. By means of the Crossley, Mr. Perrine also secured a position of Phoebe, the ninth satellite of Saturns July 18, $14^h\ 41^m\ 23^s$ p.s.t. as follows:

Right Ascension	$23^h\ 5^m\ 12^s.85$
Decl.	−7° 59′ 36″.0

and, with respect to Saturn:

1^m	$10^s.35$	west
6′	53″.5	south

This position is within 1^s in right ascension and 0′.1 in declination of the place predicted by Ross for it.

Other observations were secured on July 19, 20, August 14, 16 and 17. On September 12, 1906, Mr. Perrine remarked that the satellite was too near to the planet for observation with the Crossley reflector.

F. G. W. Struve's Double Star Work as collected and discussed by Thomas Lewis, London Royal Astronomical Society, Burlington House, London, 1906, has recently been reviewed critically by Professor R. G. Aitken of Lick Observatory. This review covers five pages of the last issue of *Publications of the Astronomical Society of the Pacific*, No. 110. Those prosecuting double star work will find much late and useful information in this review.

Approximation of the Greatest Root of a Cubic Equation with Three Real Roots. We are concerned with the "irreducible case," in which Cardan's formula is of no value for computation. By replacing x by $-x$ if necessary, we need consider only the form

$$x^3 - ax - b = 0 \ (a \text{ and } b \text{ positive}) \quad \ldots(1),$$

the two lesser roots of which are negative and the greatest root, which equals the sum of the lesser ones, is positive. It can be shown* that the greatest root g lies between the limits $\sqrt{a}$ and $\sqrt{(4a/3)}$. From equation (1) we obtain

It is evident that if we assume for g an approximate value less than the true one, and substitute it in the right hand member of equation (2), the resulting value will be greater than the true value; if we assume for g, a value greater than the true one, the resulting value will be less than the true value.

For a first approximation to the value of g, assume any convenient positive value between the limits $\sqrt{a}$ and $\sqrt{(4a/3)}$. For a second approximation, substitute the first approximation in the right hand member of equation (2) and compute the resulting value; etc.

This will give a series of approximations, alternately less and greater than the true value, towards which they converge as a limit.

Example. $x^3 - 6x - 2 = 0$.

$$\sqrt{6} = 2.449,$$

$$\sqrt{6 + \frac{2}{2.449}} = 2.610,$$

$$\sqrt{6 + \frac{2}{2.610}} = 2.601,$$

$$\sqrt{6 + \frac{2}{2.601}} = 2.6019,$$

$$\sqrt{6 + \frac{2}{2.6017}} = 2.601677,$$

the last being correct to five decimals.

CHARLES GILPIN, JR.
In American Mathematical Monthly.

Queries. If the stellar magnitude of the Sun is −26.4, say $26^{m}.5$, it follows, that if we had a telescope large enough to show stars down to the $26^{1}/_{2}$ magnitude then a star of the first magnitude would appear as bright as the Sun when viewed with it. How large would such a telescope have to be? If the Lick telescope of 36 inches aperture shows stars down to 16.5 magnitude, which is 10 magnitudes brighter than 26.5, and the naked eye is able to detect stars of 6.5 magnitude which is 10 magnitudes brighter than the faintest seen in the Lick instrument, then the proportion ought to be the same between the latter and the one we wish to find the size of, as between the eye and the Lick telescope! If the pupil of the eye is one-fifth of an inch in diameter and the Lick thirty-six inches then our telescope would have to be 180 times the diameter of the Lick telescope, which is 540 feet, providing of course that no light gets lost.

Now do you think that with such a telescope Aldebaran or Altair could be magnified to appear as large as the Sun, or, owing to the brilliancy of Altair, it would appear as bright even with a smaller disk? F. A.

*$g > \sqrt{a}$ by (2). Since $b^2/4 - a^3/27 < 0$ in the irreducible case, $x^3 - ax - b$ is positive for $x = \sqrt{(4a/3)}$, negative for $x = \sqrt{a}$,

$$x = \sqrt{a + \frac{b}{x}} \ldots (2).$$

Correction. In POPULAR ASTRONOMY, Vol. 14, page 244, the following correction should be made:—

	h	m	°	′				
U Librae	R.A. 15	36.2	Dec. −20	25	for	5.8	read	<12
Z	"	40.7	−20	49	"	9.0	"	11
R Coronae		44.4	+28	28	"	9.1 *i*	"	5.8
—	"	45.3	+37	49	"	11.0	"	9.0
V	"	46 0	+39	52		<12	"	9.1 *i*

The errors were not due to observation, but to a curious interchange of magnitudes which occurred in preparing the manuscript. Attention was called to them by a letter of Miss O'Halloran, who pointed out the discrepancy in magnitude in the case of V Coronae.

E. C. P.

Errata: November, 1906, Number, page 566

In N 42′ should read 41′
ω 18° should read 19°
Period 9.66633 should read 6.66633

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